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IRAS: Mission Infrared

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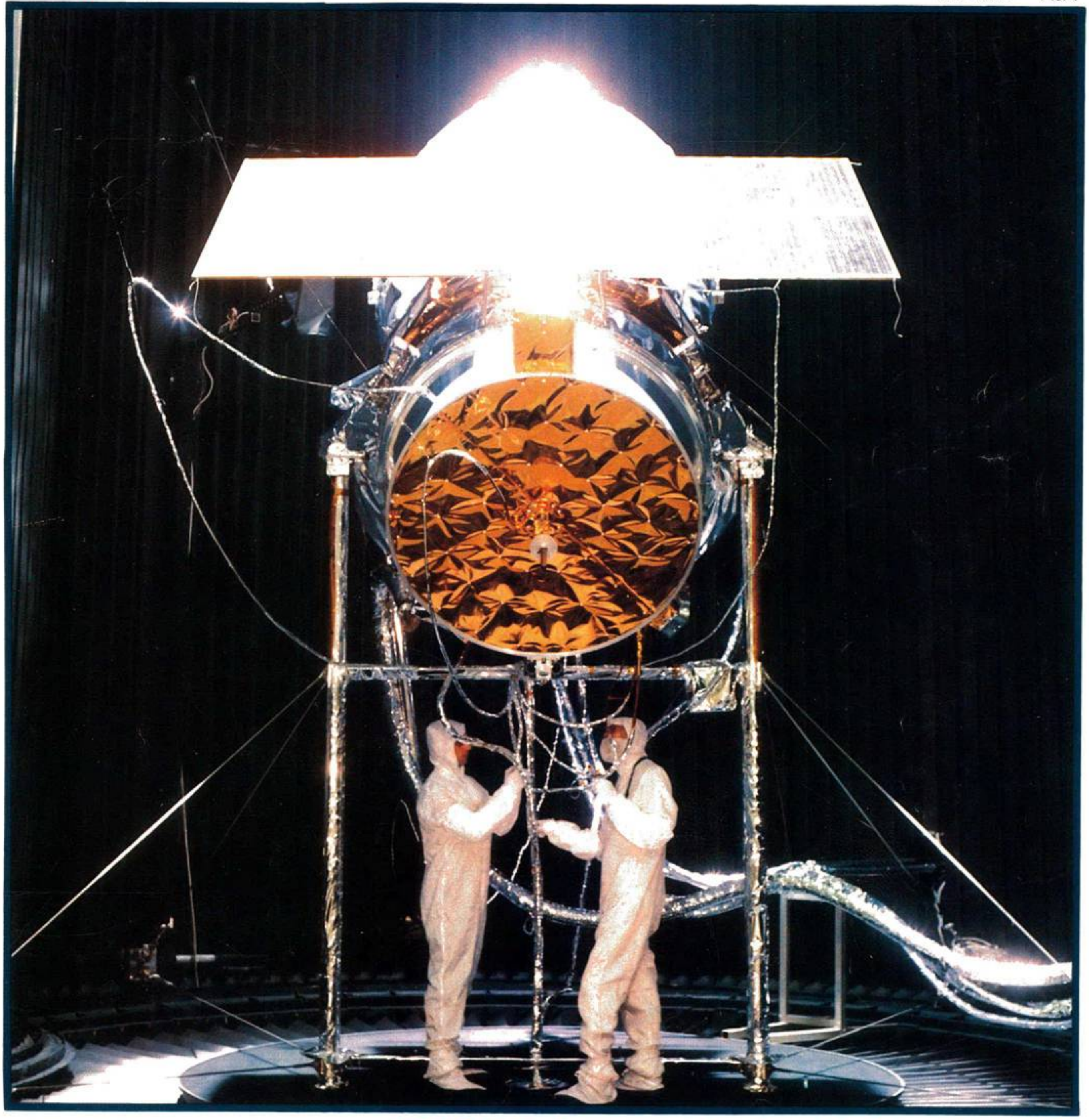
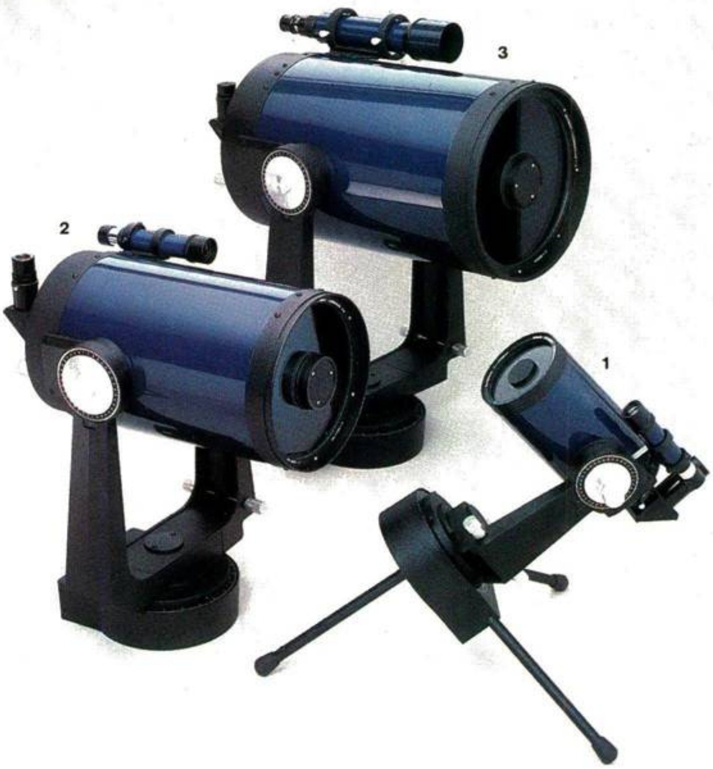
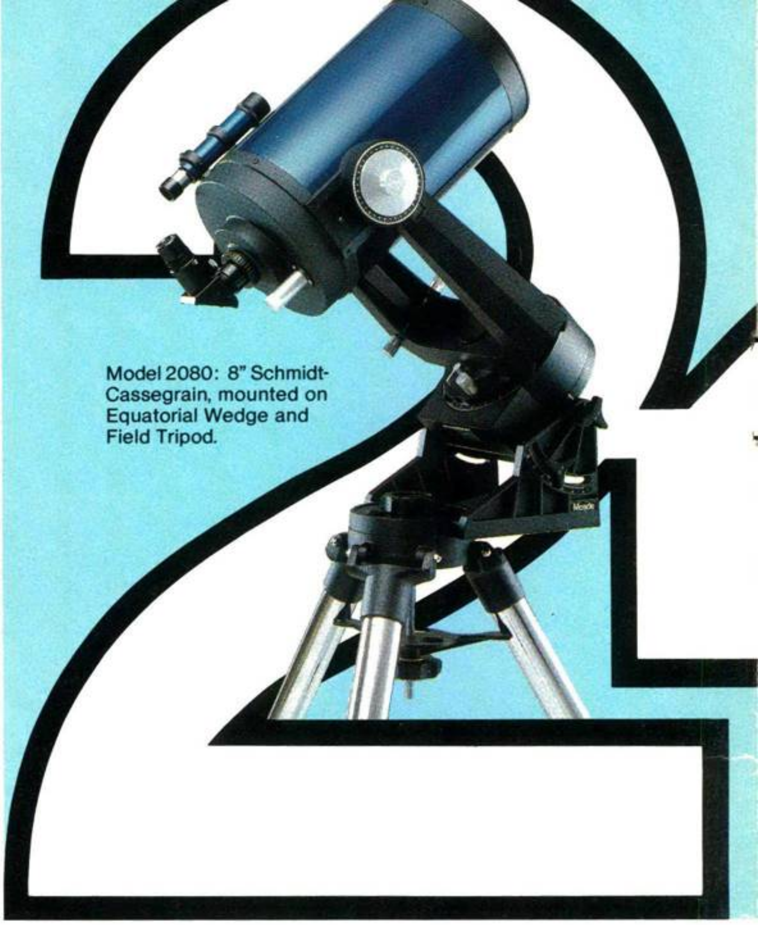


IRAS Undergoes Testing Before Launch

Meade Schmidt-Cassegrain Telescopes: **(1)** 4" Model 2044, with standard-equipment table tripod; **(2)** 8" Model 2080; **(3)** 10" Model 2120.





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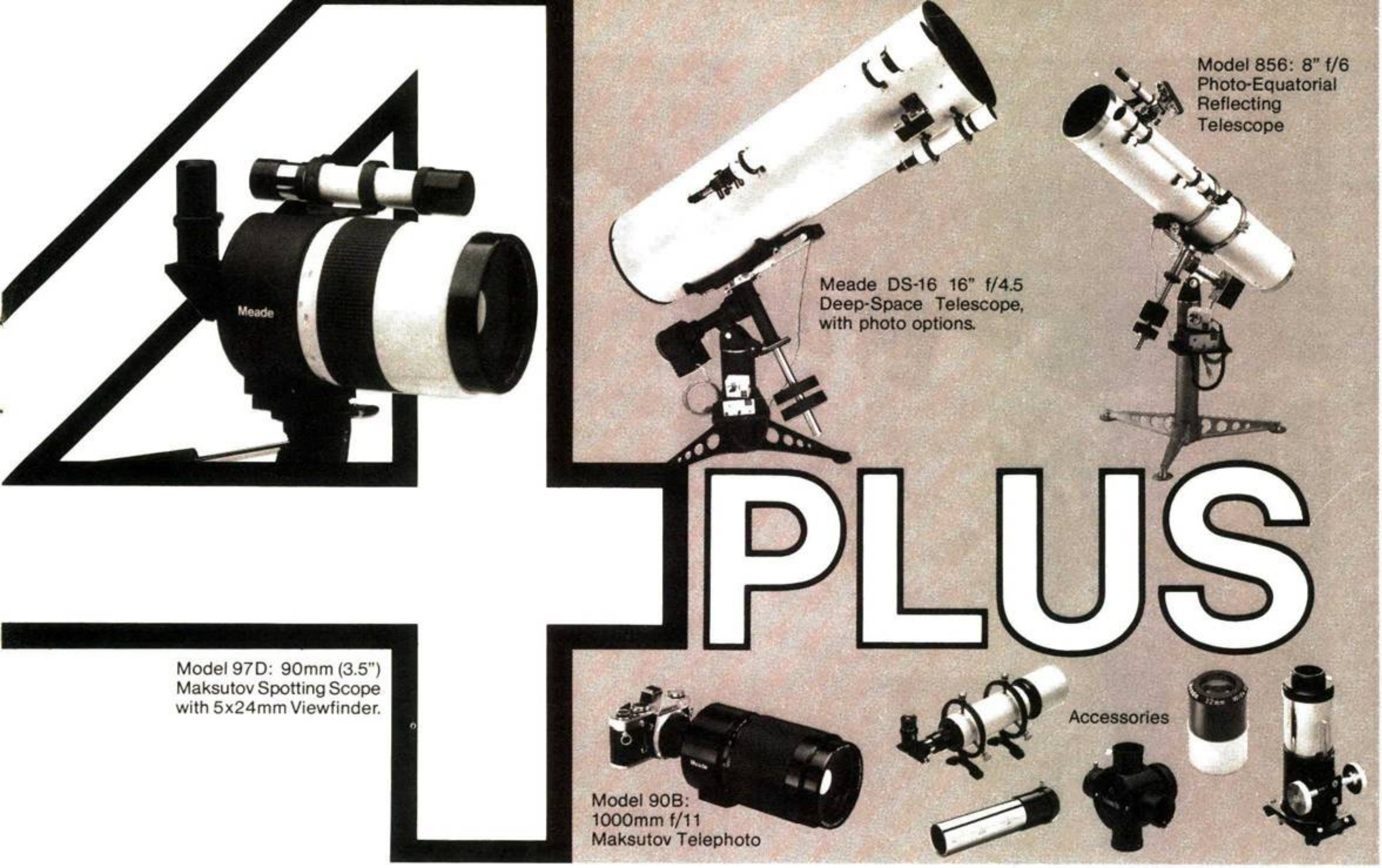

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6 **IRAS and the Infrared Universe**
by Robert Burnham

Forum **24** **Hollywood Astronomy**
In Focus **32**
Behind the Scenes **33**
Gazer's Gazette **34** **Probing the Constellations of Spring**
by Earle F. Dodds
Astronomy Reviews **39**
Eye on the Sky **42** **Venus Shines at Sunrise**
by Fred Schaaf
Photography in Astronomy **51** **Be a Copy-Cat!**
by Clive Gibbons
AstroNews **60**
Stellar Frontiers **66** **The Planck Era**
by Sten Odenwald
AstroMart **72**
Equipment Atlas **76** **A Homemade Finder Scope Mount**
by Randall Wehler
The Backyard Astronomer **78** **Coma Berenices**

Cover: Though little known to the general public, one of the most exciting missions of recent years was the Infrared Astronomy Satellite — IRAS for short — shown here undergoing thermal tests at the Jet Propulsion Laboratory in California. NASA photo. ASTRONOMY's feature article this month delves into the new infrared universe this satellite has revealed to us. On these pages, a portfolio of images that document IRAS' development, testing, and launch. Photos courtesy of NASA (background) and Fokker.

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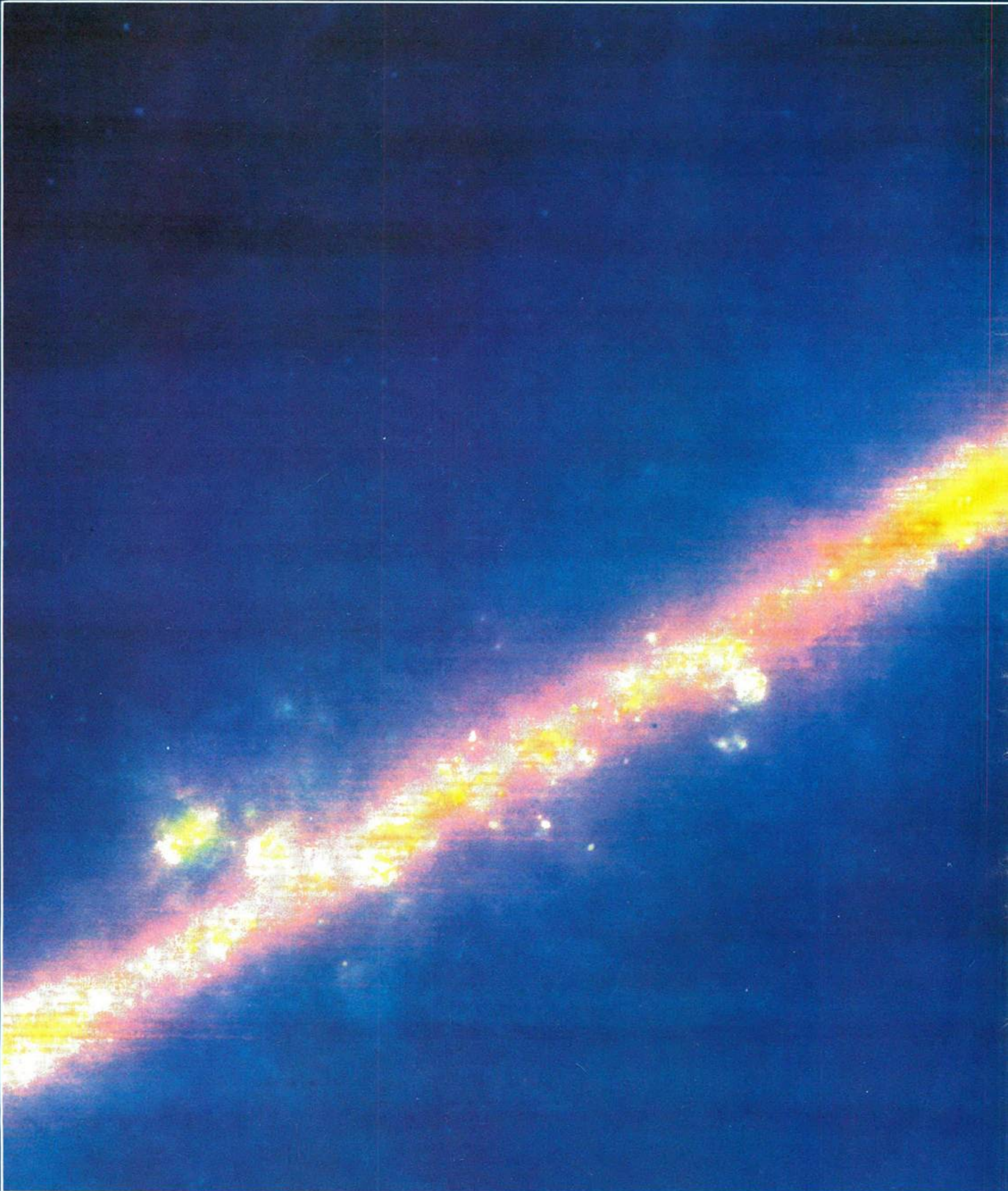
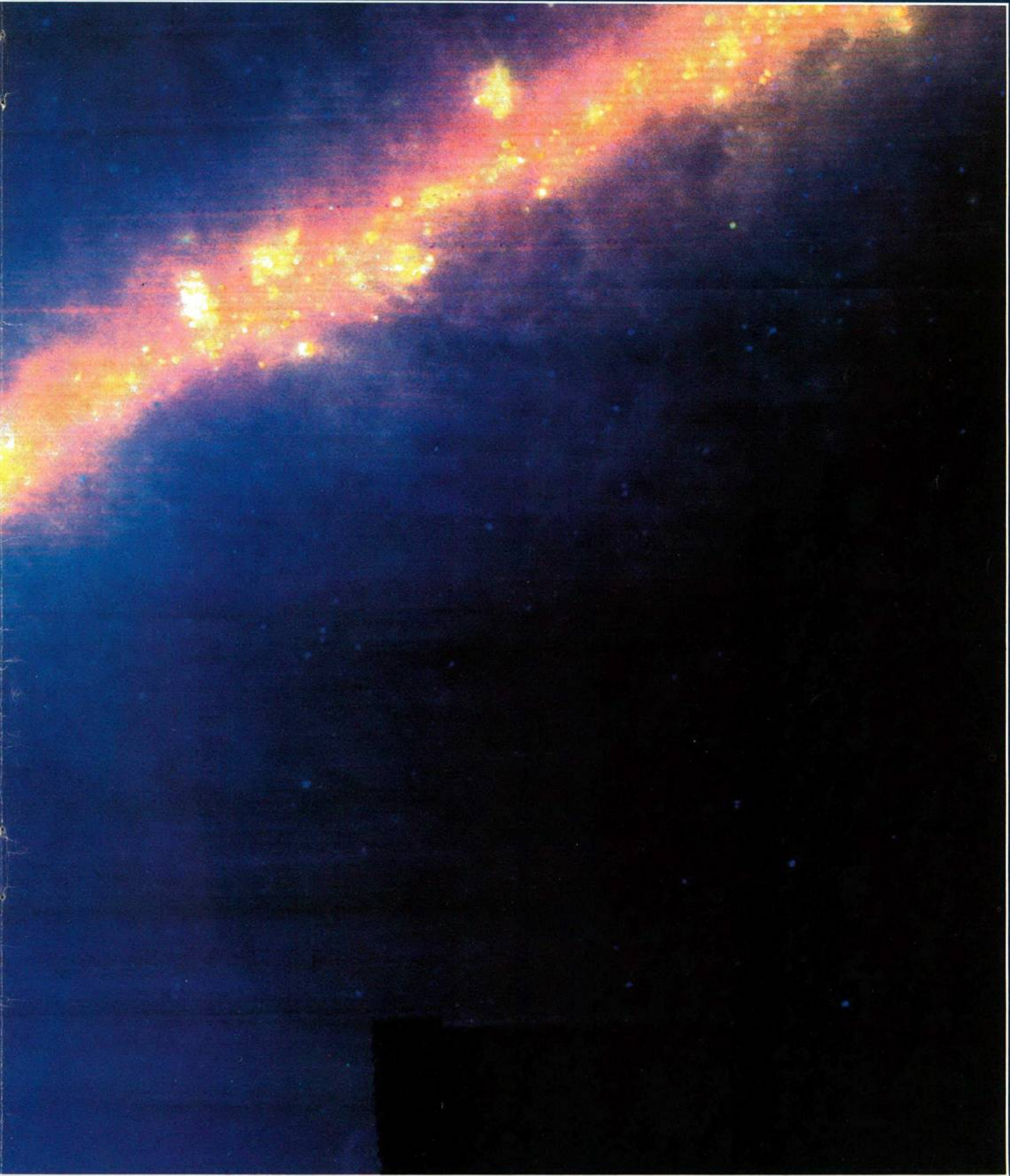
IRAS & THE INFRARED

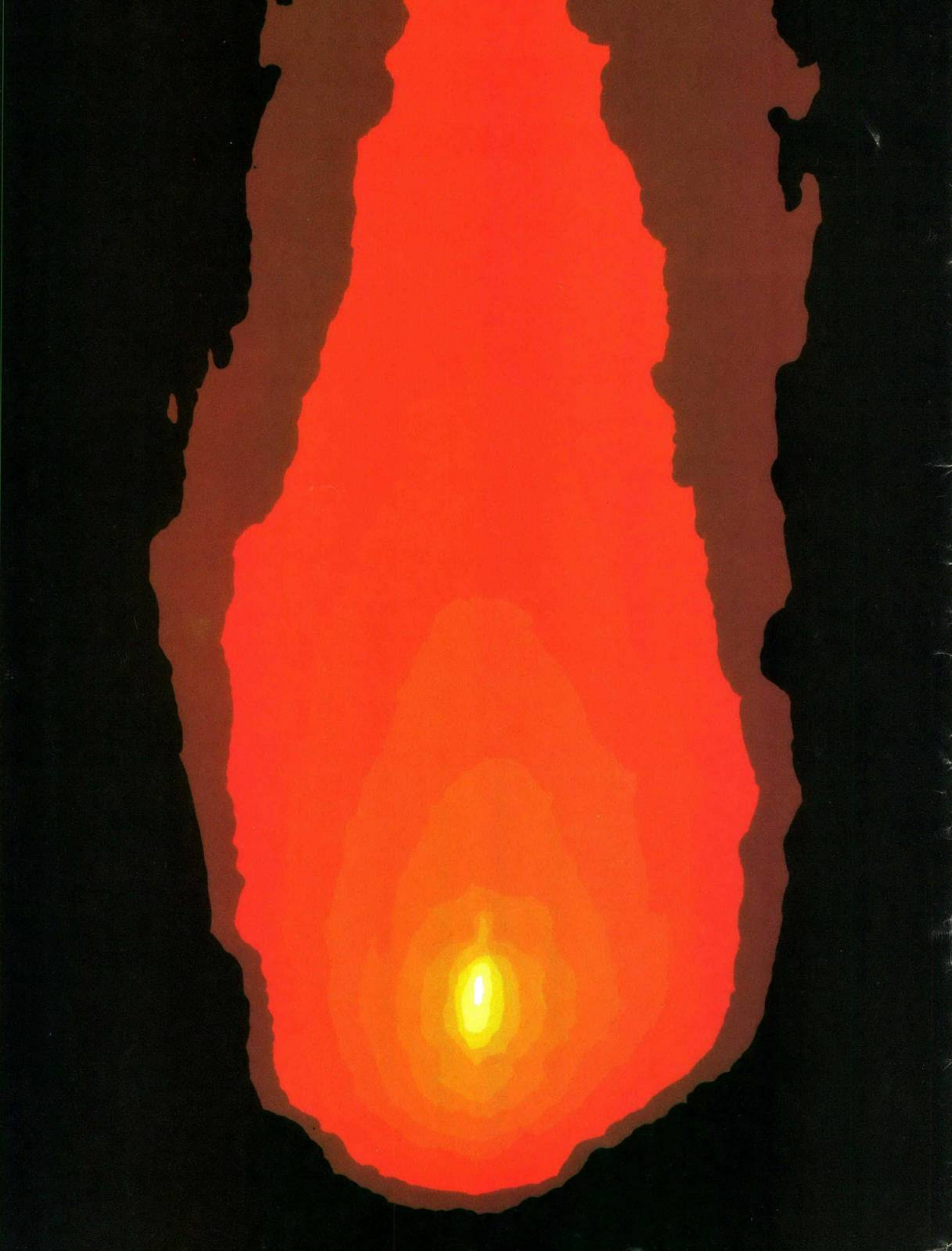
by Robert Burnham



UNIVERSE

Dust throngs the plane of the Milky Way in a narrow band. This picture is a false-color composite made from separate IRAS images taken in four infrared wavelengths. All images in this article are from NASA.





The universe is a far dustier place than anyone ever imagined. Dust envelops the solar system and is liberally scattered throughout it. Dust surrounds several of the brightest stars in the sky and clumps thickly around the hydrogen-rich regions of star birth. Even dark molecular clouds known to be dusty turn out to be richer in dust and more far extensive than previously suspected. Galaxies have been found that are so dusty as to be 50 times brighter in the infrared than in the visible. And looking outward toward the limits of the known universe some objects — galaxies? quasars? — appear to be buried behind enough light-years of dust that they are entirely invisible.

How do we know this?

In late January 1983, a one-ton satellite was launched into Earth orbit from Vandenberg Air Force Base on the California coast. Known as IRAS (for Infrared Astronomy Satellite), its task was to survey the entire sky at four infrared wavelengths and accumulate sufficient data that the project scientists could compile the first detailed catalog of objects in the infrared sky (see "IRAS: Mission Invisible," ASTRONOMY, April 1983).

Last November, its supply of coolant ran out and the satellite shut down. During its 11-month life, IRAS delivered an immense quantity of data — which was expected — and it uncovered several new features of the sky — which were not.

Some clear evening late this month, drive out of town far enough to get well beyond the lights of the city. About an hour or two after sunset, you'll see in the west a faint triangular wedge of light pointing up away from the horizon toward the Pleiades. It is about as bright as the Milky Way and lies along the ecliptic. What you are seeing is the zodiacal light — a soft glow produced by sunlight reflecting from uncountable billions of tiny particles of dust in orbit around the Sun.

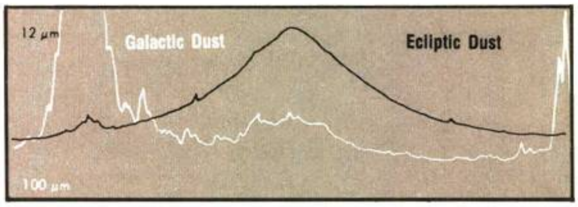
Interplanetary dust comes from many different sources, but mostly from comets and collisions between asteroids. Ranging from perhaps a centimeter across (extremely rare) down to the microscopic (extremely numerous), a dust particle circles the Sun for a time that depends entirely on its size. The small particles — those under 0.001 mm diameter — will be blown out of the solar system in about a year by the pressure of radiation from the Sun. The orbital velocity of particles in the 0.01 mm to 1 cm range, on the other hand, is slowed by solar radiation. They spiral into the Sun and are destroyed in about 100,000 to 1 billion years. Particles larger than this are massive enough to remain in orbit over the lifetime of the solar system itself.

The zodiacal material orbits the Sun generally in the same plane as the planets — hence its name. In this it differs markedly from the larger objects known as asteroids — chunks of rock ranging from a few meters across to over 1,000 kilometers in diameter. Their average orbit inclines some 30° to the ecliptic, and most circle the Sun at a distance of about 2.1 to 4.0 astronomical units (AU) — between the orbits of Mars and Jupiter. Some, however, have very eccentric paths that bring them inside the Earth's orbit.

Comet IRAS-Araki-Alcock, a bright visitor to the night sky last spring, was the first comet discovered by a spacecraft. This image, made from data taken at 25 μm wavelength, shows an extensive coma of dust surrounding the comet.

Before IRAS, astronomers knew that the asteroid belt contained a sheet of dust lying just about in the plane of the ecliptic — a result of multiple collisions between asteroids. But IRAS revealed a more complex situation: the clumping in the plane of the solar system is flanked by two other bands of dust 8° to 10° above and below it. This shows most strongly in the IRAS data at a wavelength of 60 μm, which corresponds to a temperature of 165° to 200°K. (One μm is one micro-meter, a thousandth of a millimeter or 10,000 Angstroms.) This is the temperature that dusty material would have at a distance from the Sun equal to that of the asteroid belt. The central band plus the two flanking ones resemble folded mountains paralleling a central ridge; they are found all the way around the ecliptic.

Generally speaking, a feature such as this cannot exist for long — inter-particle collisions, solar radiation pressure, and gravitational perturbations by the other planets will tend to mix the material into a more homogenous state in the plane of the ecliptic. Frank Low of the University of Arizona, one of the IRAS science team members, estimates that particles in the bands have orbital lifetimes of only a few tens of thousands of years.



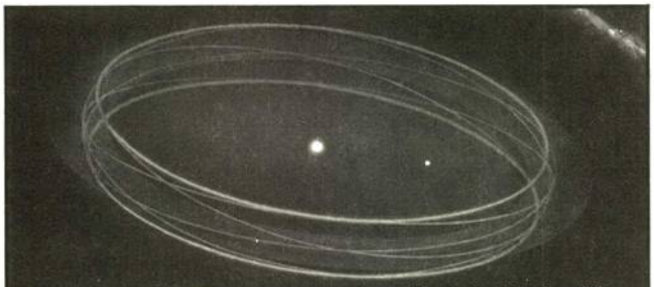
At 12 μm wavelength the ecliptic is bright, but at 100 μm, the infrared radiation of the Galaxy predominates. All diagrams from NASA.

Where have these bands come from? Two hypotheses offer possible explanations. The first suggests a single collision between an asteroid and a 9°-inclined comet. This has two things in its favor: an attractive simplicity, and the fact that comets have long been considered the main source for zodiacal dust. But opinion among the IRAS scientists runs against it because the mechanism is too haphazard. They prefer the second hypothesis, which calls for multiple collisions between asteroids with orbital inclinations of about 9°. Though this may seem just as haphazard, collisions between asteroids are known to be fairly common (which is not the case with comets and asteroids).

In this model, the impacts would inject a spray of dusty debris into a somewhat elliptical orbit taking the material 9° above and below the plane of ecliptic. Perturbations would then slowly precess the ring of debris and distribute it more evenly around the ecliptic while preserving the 9° inclination. Contrary to what you might expect, precession would not simply degrade the bands into one smooth 18°-wide band: due to Kepler's laws of orbital motion, each particle tends to spend most of its time at either the +9° or −9° point of its orbit. Dust thus "collects" at those inclinations and preserves the structure as long as it remains. Although the bands IRAS saw are relatively transient, there is nothing to prevent similar impacts from creating such features again — as they probably have in the past.

Can we pin down just which asteroids may have collided to create the dust? There is no definite answer as yet, but recent work by Stanley Dermott, Philip Nicholson, and Joseph Burns at Cornell indicates that the three most populous families of fragmented asteroids have orbital characteristics similar to what the dust apparently has. Two of these families, the Themis and the Koronis groups, have inclinations of 1° to 2° and could have given rise to the clump of dust in the ecliptic plane. The third family, the Eos, has an orbital inclination of about 10° — very close to that of the flanking dust bands. More work must be done before astronomers can claim that the dust came from the collisions that created these families of asteroids, but the evidence is strong in its favor.

Though they may not have contributed to the banded structure of dust in the asteroid belt, comets shed prodigious quantities of dust into the interplanetary medium all by themselves. The first comet ever discovered by a spacecraft — Comet IRAS-Araki-Alcock, found last April — was a typical, albeit spectacular, example. IRAS-Araki-Alcock was intrinsically a faint comet, but because of its close approach to Earth (see "A Shot Out of the Dark," ASTRONOMY, August 1983), it appeared fairly bright. As it swept past Earth, the comet was examined in detail by ground-based observers and IRAS. The IRAS data showed that a Sun-warmed dust tail extended some 400,000 kilometers out from the nucleus, containing "a major fraction of the observable mass of the comet," according to Russ Walker of Jamieson Engineering and a member of the IRAS science team.

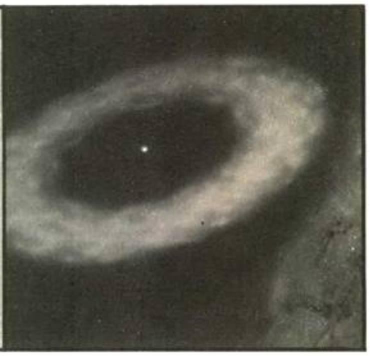


This artist's conception shows how the zodiacal dust bands might look. The Sun is in the center and Earth lies to one side of it.

Although IRAS-Araki-Alcock is a very dusty comet, it may not be all that unusual. The infrared satellite has found a total of seven new comets, all of which are dusty, and has revealed that many previously known optically faint comets are relatively bright in the infrared, since they have very dusty comas.

Much of the dust shed by comets goes to replace material drawn in by the Sun, but some of it can be seen on any dark night as meteors. An hour's watch on a given night shows a few meteors coming from random directions. But at certain times of the year, you'll see increased numbers of meteors appearing to radiate from one point or another on the sky. These meteor showers return on about the same date each year and take the name of the constellation in which they occur.

The apparent divergence of streaks in a meteor shower is really only an effect of perspective — what you are actually seeing is objects moving in parallel paths as they impact the Earth's atmosphere. These are fluffy bits of debris (about as cohesive as cigarette ash) traveling in the orbit of a comet. Of the 10 to 20 bright showers each year, most have been traced back to a cometary "parent." Halley's Comet, for instance, spawns the Orionids of late October and the Eta Aquarids of early May, and Comet Swift-Tuttle produces the Perseids of mid-August. But one well-known shower — the Geminid in mid-December — has lacked a known parent body.



The particles in orbit around Vega most probably form a ring-like cloud. They are materials left over from Vega's formation.

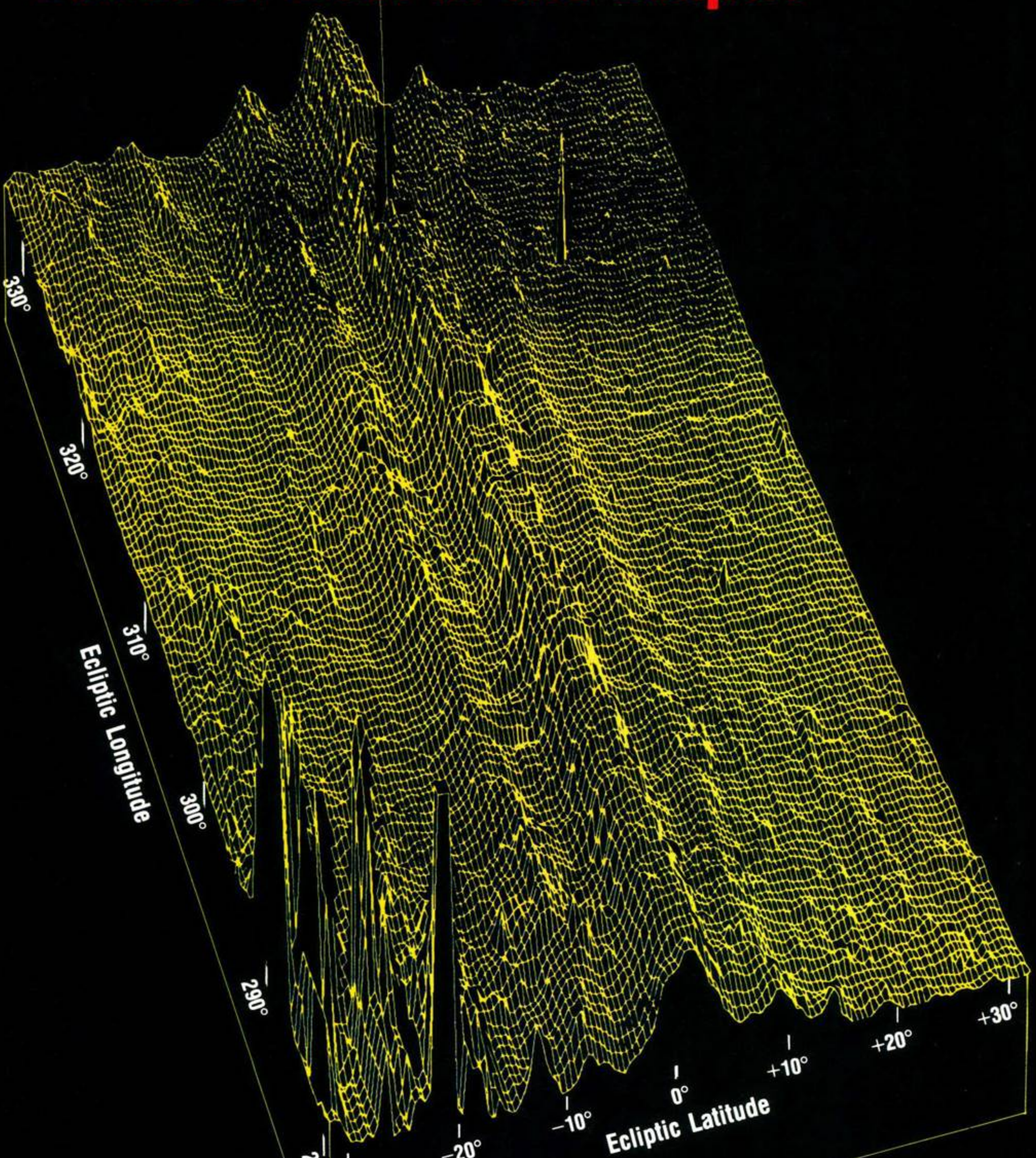
No longer. On October 11 last year, IRAS spotted a swiftly moving 16th magnitude object in the constellation Draco, which in due course received the provisional designation 1983 TB. Since the object produced a crisp trail on long-exposure photographs (and lacked the fuzzy nimbus that would betray a comet), astronomers initially thought 1983 TB was simply another Apollo-Amor object, one of a well-known class of "Earth-crossing" asteroids. But when more observations allowed them to compute its orbit accurately, astronomers realized that 1983 TB was following almost exactly the path the Geminid meteors were known to take. The parent comet for the Geminids had been found.

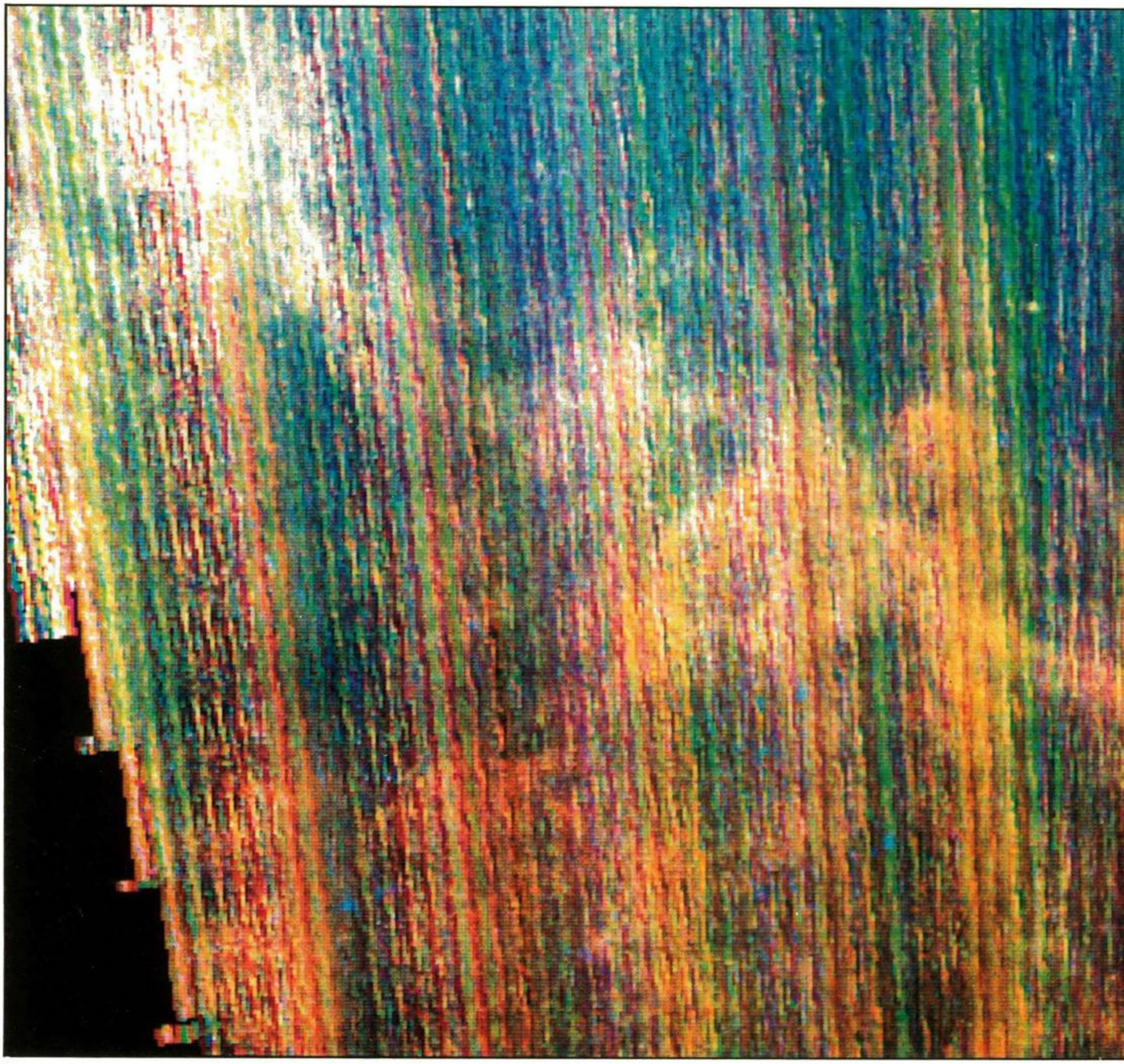
But what a miserable specimen of a comet! No ices, no outgassing, no coma, tail, or activity of any kind has been observed from it so far. Instead we see an apparently bare piece of rock less than two kilometers in diameter, which swings every 1.5 years from within 15 million kilometers of the Sun's surface (closer than any asteroid) out to 2.5 AU at aphelion. If this is the parent comet for the Geminids — and astronomers have little doubt that it is — then the object is a burnt-out remnant. Repeated close approaches to the Sun have long since boiled away all of the comet's volatiles and reduced it to a carbonaceous cinder. All that is left of its former splendor is the debris that litters its orbital path — which the Earth encounters each December 14th, in what is one of the year's most plentiful displays of meteors.

To planetary scientists, 1983 TB is an especially important find, since it provides a clear link between comets and certain types of asteroids — the carbonaceous Earth-crossers, which are suspected to be burnt-out comet nuclei. Previously, the idea that these special asteroids were comet nuclei was based on the assumption that comet nuclei would be carbonaceous and on observations that showed a distinct carbonaceous "signature" in the spectra of sunlight reflected from some Apollo-Amor objects. Though strong evidence, it was not really conclusive enough — and 1983 TB has removed a nagging

Three bands of dust lie in the ecliptic, the plane of the solar system. The largest centers on 0° *ecliptic latitude*, and has flanking "ridges" at plus and minus 9°. In this pseudo-block diagram, the bands show as ridges, and individual sources (such as planets or asteroids) show as spikes.

Bands of Dust in the Ecliptic





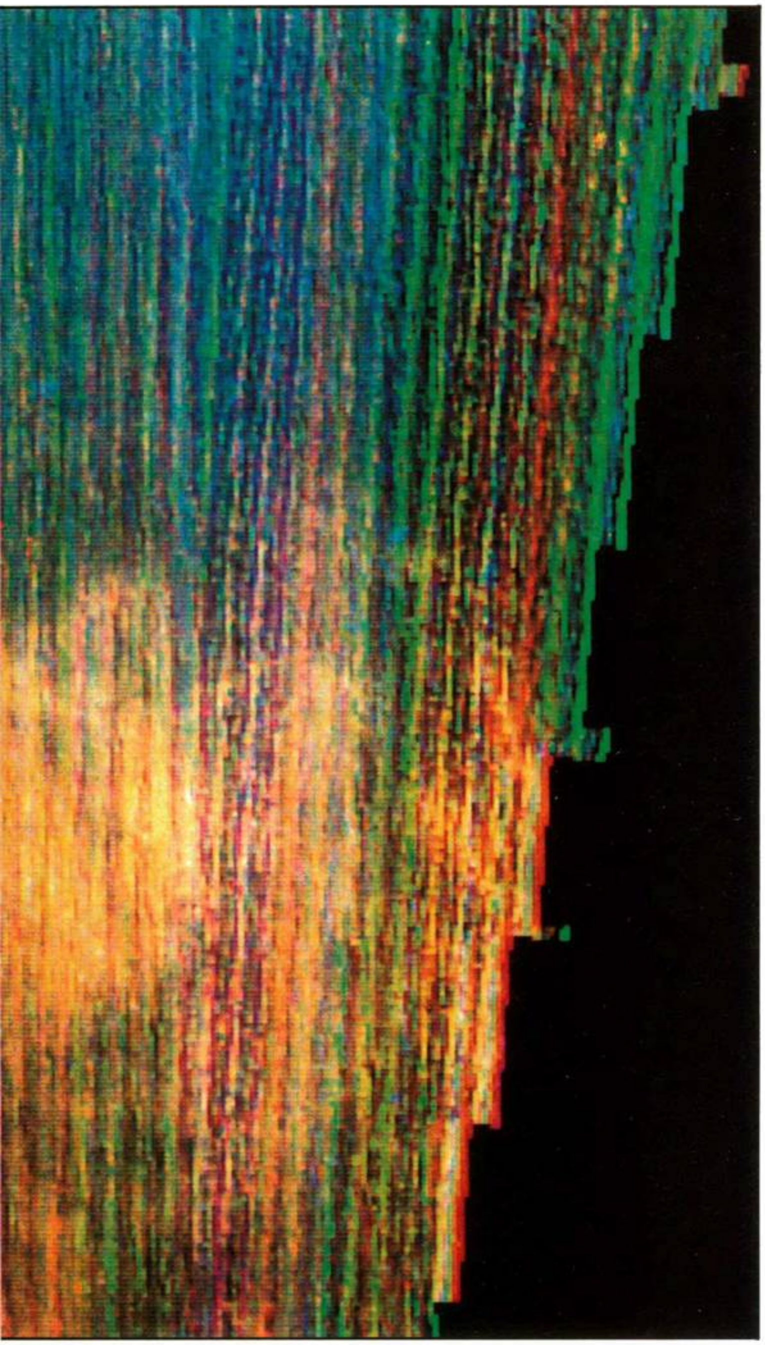
One of IRAS' most surprising discoveries was a faint wispy haze that is found all over the sky and is very cold. Astronomers called it "cirrus" after its resemblance to the terrestrial cloud form of that name. No one yet knows how far away it lies, but it is at least 1,000 times farther from the Sun than Earth.

uncertainty.

In the course of its sweeps across the sky, detectors aboard IRAS picked up another celestial feature, previously unsuspected, which has proven difficult to link to *any* astronomical object. Seen all over the entire sky, partly at 60 μm but much more strongly at 100 μm wavelength, it takes the form of a very faint haziness with a distinct wispy structure. Because it loosely resembles a type of terrestrial cloud, the IRAS project scientists have called it "cirrus." This cirrus material is extremely cold — about 35°K — and it is most likely made of dust. Thirty degrees K is the temperature of graphite dust grains exposed to the general interstellar flux of radiation; this is certainly what the cirrus chiefly consists of. (Silicate grains, the other good candidate, do not insulate as well; they radiate heat better and would therefore maintain a colder temperature — around 15° to 20°K.) The cirrus grains are about as big as tobacco smoke particles.

But what does the cirrus belong to? The Sun? The Galaxy? Or is it part of the structure of the universe itself? Logic and experience favor a relatively nearby (interstellar) location, since the farther off the material is, the more of it you need to account for all that we see — and in nature simpler explanations tend to be right more often. The first way to approach this problem would be to measure the cloud's distances. But after performing a parallax calculation, based on observations six months apart, the IRAS scientists could only say that the clouds lie at least 1,000 AU from the Sun.

Although this is a great distance, remember that the Sun's domain does not end at Pluto's aphelion, some 50

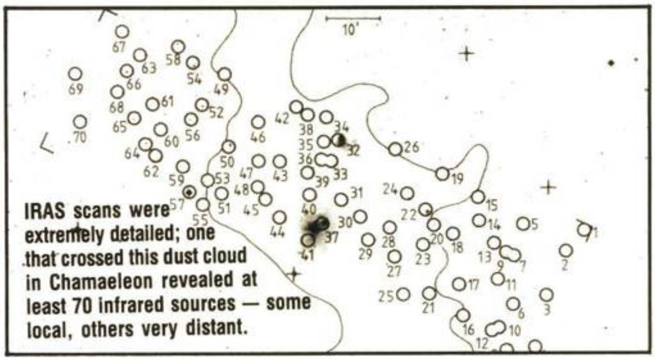


AU out. Comets have extremely elongated orbits and periods measured in thousands of years; their aphelia extend to several hundred AUs. Moreover, decades ago Dutch astronomer Jan Oort proposed that the solar system is surrounded by a spherical shell of "deep-frozen" comet nuclei extending to perhaps 50,000 AU. This has since been termed the Oort cloud and has been a constant feature in all recent theories of the solar system's origins. According to the current model for the cloud, from time to time something — perhaps a perturbation by a nearby star — may nudge one of these comet nuclei a little and send it on the long journey sunward. Ages later, as it races through the inner solar system, it glows brightly under the warming rays of the Sun and sheds a long tail of gas and dust. The comet may also have its orbit altered into a shorter period by gravitational interaction with one of the planets — or it may even be ejected from the solar system altogether.

Are we in fact seeing the Oort cloud in the IRAS-discovered cirrus? The project scientists don't know. They cannot tell how far away the cirrus clouds are, but "it is not so far that we can exclude them from being part of the Oort cloud," says Low. "This is obviously one of the most intensely pursued areas of investigation." But, according to Low, at least some of the cirrus cannot be local — small amounts of it have been positively identified with certain distant clouds of cold neutral hydrogen gas belonging to the Milky Way Galaxy and previously observed by radio astronomers. These regions of neutral hydrogen gas line the Galaxy's spiral arms and are part of the raw materials from which the Galaxy's stellar "factories" create new generations of stars.

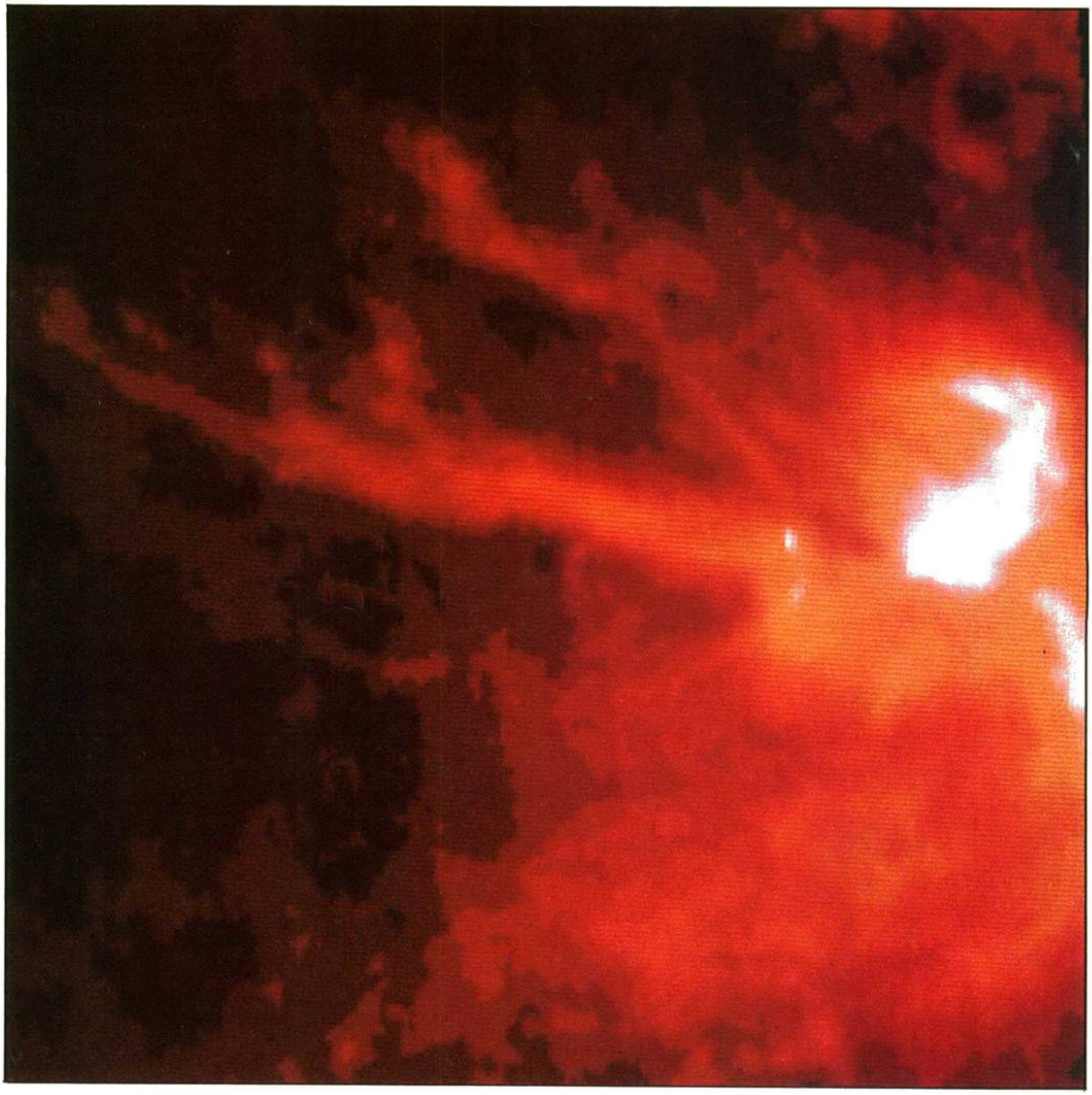
Since the advent of sensitive detectors in the 1950s, ground-based infrared astronomy has made great strides in exploring the birthplaces of stars — clouds of dust rich in molecular compounds and containing a few tens to a few hundreds of solar masses of material. This has been largely a matter of luck, since we have several examples of such regions relatively nearby. The best-known of these is M-42, the Orion Nebula, dimly visible to the naked eye in the middle of Orion's sword and whose greenish glow spills out of the field of view of a backyard telescope.

But until now, infrared astronomers have been dogged by the problem of sensitivity. Since ground-based work can detect only strong signals, astronomers have been forced to observe just the brightest proto-stars — roughly those with 10 times the mass and 100 times the luminosity of the Sun. Such stars are relatively rare so it has been a persistent drawback that astronomers could not observe and trace the early evolution of low-mass stars like the Sun. IRAS has changed that and in the process has also found that fully a third to a half of even the smaller molecular dust clouds — those thought on the basis of radio observations to be quiescent and stable — also contained sources of cool infrared emission, presumably very young stars.



IRAS scans were extremely detailed; one that crossed this dust cloud in Chamaeleon revealed at least 70 infrared sources — some local, others very distant.

One dark cloud of dust and molecular hydrogen about 1,000 light-years away in the direction of Perseus, is known as Barnard 5 (after its discover, E.E. Barnard). In it, IRAS observed four individual objects. One of these is radiating about 10 times as much as the Sun does. IRAS shows it to be a star much like the Sun, but only about 100,000 years old and thickly buried in the warm dust from which it formed. Then IRAS discovered three more objects — two of which are also young stars, but further along in their development. They, too, are still surrounded by clouds of dust at about room temperature. The scientists are more uncertain about the fourth object in the cloud. Only a few tenths of a light-year across, it appears to be

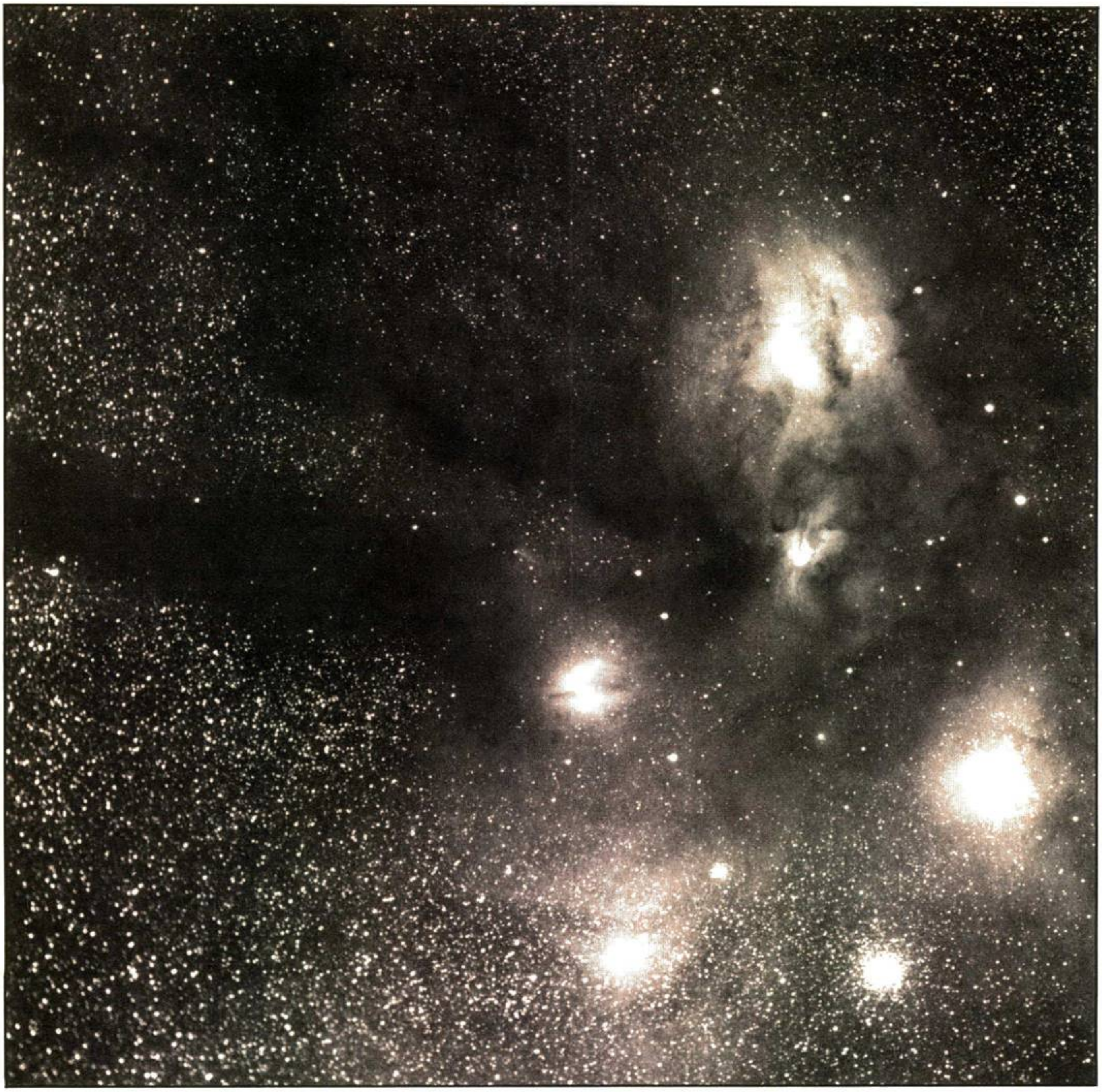


Ever since E.E. Barnard photographed it over 60 years ago (photo at right), the Rho Ophiuchi dust complex has been studied intensively by astronomers. In a way, the IRAS view (above) is almost a negative of the visible-light photo. In Barnard's photo, stars shine brightly and are obscured by dark lanes of dust and molecular hydrogen. To IRAS, the stars are too dim to be seen, but the warm glow of dust streamers shows how large the complex really is.

either a cold (30°K), compact lump of material or a cloud beginning to collapse to form an infant star.

In the vicinity of another dark molecular cloud, in the constellation Chamaeleon, IRAS scans uncovered 70 individual sources. Although some are background objects, 17 of the 70 are similar to those in Barnard 5, and represent either still-forming stars or very young stars shrouded in dust. Another 25 objects are cool clumps of stellar material that have yet to collapse into stars — and maybe never will.

This points out one of IRAS' most powerful functions: for the first time, astronomers can look into and *through* these dust clouds to inventory what they contain. For the nearer ones — out to 2,000 light-years, say — a complete list of contents can now be drawn up; with decreasing precision, this can be carried out for more distant clouds, as well. The end result will be a clearer picture of how dusty clouds of molecular hydrogen collapse into knots and create stars — and in turn we will gain a better understanding of how the star-making machinery of our spiral galaxy works. Though the actual work of sorting and making sense out of the flood of data will take years, a cursory examination already shows that star-formation, especially for smaller-mass stars like the Sun, is a far more common process than previously suspected. To judge from the number of proto-stars IRAS has seen, the Milky Way Galaxy must be producing about one Sun-like star each year — a figure appreciably higher than earlier



estimates.

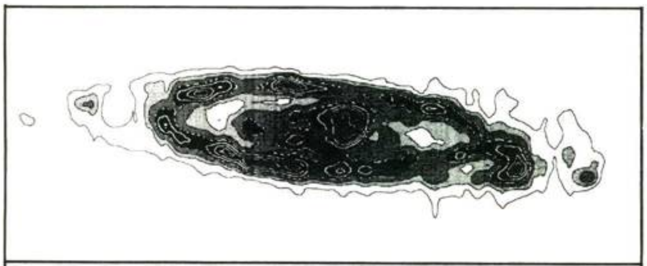
Besides looking deeper into these clouds, IRAS' great sensitivity has also shown that in many cases, the borders of known regions of star formation (determined from previous ground-based studies) were much too limited. In reality, most molecular clouds extend much farther than astronomers figured. The Rho Ophiuchi complex, shown on these pages, is a typical example. Another is the Orion region, where the material that pervades it stretches to great distances. Selected parts of the Orion complex had been known and investigated long before, but the IRAS data showed that the interconnections were very extensive.

When a star forms, it is typically surrounded by a ring of material called a stellar nebula. Although most of this blows away as the star matures, if conditions are right, some of it may condense to form planets — as happened with our Sun. But we have no way to know how often this process happens. Thus it's hardly surprising that the one IRAS discovery to capture the imagination of the public was the ring of particles orbiting the star Vega. Over the past two decades, astronomers have occasionally announced evidence — sometimes weak, at other times apparently quite strong — for the existence of solar systems around other stars. But none of these have held up to rigorous scrutiny.

Although there is small hope that the Vega system has planets as we know them — and even less chance of life — the IRAS finding is extremely important, since it unquestionably shows circumstellar material in orbit around another star. Although astronomers had the example of the solar system to work with, it's always risky to draw conclusions from a sample of one.

The Vega system came as a real surprise, since Vega has long been used by astronomers as a standard star for instrument calibration and has been surveyed at many wavelengths by many observers for a long time. A typical ordinary A0-class star and the brightest star in the constellation Lyra, Vega is easily visible from the northern hemisphere as it swings high overhead on summer and early fall nights. The IRAS team chose it as one of their calibration standards and were checking the satellite's scans across the star when they realized it was far brighter in the infrared than any A0 star ought to be.

Further analysis by the startled scientists showed that this excess emission came from a cloud of particles at a temperature of 85°K that was orbiting 85 AUs from Vega. "The dust particles in the cloud are very much larger than one would expect," says Fred Gillette of Kitt Peak National Observatory, one of the IRAS science team members. These particles must be at least a millimeter or larger in size, though IRAS data cannot set an upper limit. Given that they are of at least millimeter-size, however, the particles must have accreted through collisions.



IRAS also revealed the most active areas of star formation (darkest patches) in M-31, the Great Galaxy in Andromeda.

How many more Vegas are there? Other stars have infrared emission, but "Unfortunately, the presence of a cool infrared excess is not sufficient to make a case for a Vega-like system," says Gillette. "In the first place, we know that many old stars and very many young stars tend to lose mass and are creating dust in the process." A star could also be passing through a dust cloud — or it could have a cool, unseen companion star. These can all give rise to an infrared signal that appears superficially similar to that from Vega. Taking a catalog of the 9,000-odd brightest stars of the entire sky, IRAS scientists have found that only about 50 of them are reasonably promising candidates for further checking. Vegas, apparently, are scarce.

And even if more were to be found, it still says nothing about solar systems of *planets*. The difficulty is that although a system may contain many large planets, these contribute only a small amount to the total infrared emission. According to Charles Beichman of the Jet Propulsion Laboratory, "The bulk of the non-stellar mass in a system can reside in planets, but IRAS can detect only the small stuff." To take an example — if IRAS were to look at our system from the 4.3 light-year distant Alpha Centauri, the Sun would display no infrared excess and our system of planets would remain undetected.

But, as mentioned, not all dust clouds around stars indicate extreme youth — and herein lies a fascinating discovery. According to well-known astrophysical theory, in the latter stages of a star's evolution, the star may swell to many hundreds of times its normal size. Such stars are called red giants because of their size and color. One characteristic of red giants — a by-product of the physical changes going on inside — is that they periodically shed material from their surfaces at a substantial rate. This material contains a mixture of assorted elements and compounds and quickly cools to form dust upon being shed from the star. Since the expulsion of this material is episodic, the layers form shells around the star, which have been detected for some stars by the pattern of absorption lines they impose on the star's spectrum.

When IRAS swept its detectors across Betelgeuse — the ruddy first-magnitude star at the upper left corner of Orion — it sensed more infrared radiation than astronomers expected. Detailed analysis of the signals showed that red-giant Betelgeuse is surrounded by as many as three shells of cool dust. Some 500 light-years away, Betelgeuse is a mammoth star; according to direct measurements from Earth (it is one of a handful of stars for which this can be done), it is about 800 million kilometers in diameter. It varies in brightness by almost a magnitude over a semi-regular period of about six years, but with smaller fluctuations of roughly 200 to 300 days.

The IRAS results show that the three separate dust shells extend about 4.5 light-years from the star. Given their rate of expansion, the three eruptions must have occurred between 50,000 and 100,000 years ago. A curious feature about the shells is that they are asymmetric — they do not make neat concentric rings around Betelgeuse. Instead, the shells lie closer to the star on the south (as we see it projected onto the sky). Since it is highly improbable that the shells were ejected in such an asymmetric fashion, the IRAS team scientists feel that we are witnessing the effects of an interstellar wind that blows from south to north (again, in projection) in the region of Betelgeuse. As each shell was ejected, it was soon blown "downwind" of the star by the motion of the interstellar medium.

When we look toward Betelgeuse and Orion, we are looking "outside" — toward the outer rim of our Galaxy. To view the galactic center, we must look half a sky away, in the direction of Sagittarius. Our Sun lies about 30,000 light-years from the galactic center, roughly two-thirds of the way to the rim. "Behind" us (toward Orion) spread the thinly-populated outskirts of the Galaxy; inward toward Sagittarius lies all the rest of the stellar pinwheel we inhabit — and the difference is visible even to the naked eye. Sagittarius and its neighboring constellations harbor many clouds of gas and clusters of stars, and appear far brighter and richer than do the corresponding regions in Auriga and Gemini.

From this and other evidence, astronomers have known for the last 65 years where the galactic center lay, but they have been completely frustrated in their attempts to see (at visual wavelengths) what is going on there. The reason for this is simple — there is so much dust and gas in the way that visible light cannot get through. But not long after Harlow Shapley used the distribution of globular star clusters to establish the position of the Milky Way's center, pioneering radio observer Karl Jansky detected a strong radio signal coming from Sagittarius. Unfortunately, the challenge posed by his observations was not taken up immediately by other astronomers, but the path for future research to follow was clear: since visual light is extinguished by thousands of light-years of dust, observations of the center of the Galaxy must be shifted to those wavelengths where the dust is more transparent — the radio and infrared.

In the last few decades, astronomers have used ground-based observations to build up a picture of the galactic center (see "Journey to the Center of the Galaxy," ASTRONOMY, August 1980). It is thought to have a central core containing about 10 million solar masses of material, surrounded by enough layers of dust, stars, and molecular material to add about a thousand times more mass. Radio observations have allowed astronomers to calculate the velocities of the gases in and around the nucleus from their Doppler shifts. These yield phenomenal figures. For example, one feature that resembles a spiral arm lies between us and the nucleus, about 10,000 light-years out from the core. It is circling the nucleus at more than 200 kilometers per second and moving outward toward us at some 50 km/sec. It contains some 10 million solar masses. To move such a quantity of matter involves expending more than a thousand times the energy that an average star like the Sun will produce over its 10 billion year lifetime.

What is going on in the Galaxy's nucleus? No one knows for sure, although it seems clear that the core contains a lot of extremely active material — and conditions there are probably unduplicated anywhere else except in the cores of other galaxies. The lack of detailed observations has forced astronomers deep into theory and has provided a distressingly small amount of data with which to discriminate between the various models.

One suggestion invokes a massive black hole, or even several of them, in the heart of the Galaxy. In this view, the core is surrounded by an accretion disk that trickles some 10 solar masses of material each year into the black hole, releasing in the process great amounts of thermal energy to heat the surrounding dust and gas clouds. Supporting this theory are radio interferometry studies that have shown that the strongest emitting object in the region, known as Sagittarius A and thought to be the core itself, could be as small as 10 AUs across.

Another idea postulates the existence of "supermassive" stars with several hundred or a thousand solar masses each. Besides shining brightly, massive stars like these would race quickly through their life-cycles and explode, showering the vicinity with energetic radiation and exotic stellar by-products. Other suggestions call for collisions: stars from the galactic halo, some of which have orbital paths taking them through the core, might collide with stars in the core and release energy. In yet another model, dust clouds shed by giant stars in the core may collide with each other or they might impact on, and be heated by, compact highly dense objects such as neutron stars. According to one study, as many as 20 million of these might exist there.

Narrowing the focus to dust may be important. The data from IRAS in all four of its wavelength bands show the distribution of dust throughout the Galaxy at temperatures from about 250°K down to about 30°K. Moreover, the Galaxy takes on an interestingly different appearance from what you see with the naked eye or in long-exposure photographs. Seen by eye from a dark location, the Milky Way immediately impresses you with its uneven, patchy quality — even setting aside such season-to-season differences as that between Sagittarius and Auriga. For example, to the eye the stream of stars that runs from Cygnus to Scorpius appears divided by a dark lane, a result of a nearby dust cloud obscuring part of the view. There is another dust-obscured region, visible to anyone living south of about +10° latitude, in the constellations Crux, Centaurus, and Carina. No matter where you look along its length, the edges of the Milky

The Future of Infrared Space Astronomy

Launched on January 25th, 1983, IRAS finally ran out of liquid helium coolant and ceased astronomical observations on November 21st last year. This was a month or two short of the hoped-for lifetime of the craft, but about twice as long as project scientists expected when it was launched.

During its lifetime, IRAS returned about 25 gigabytes (2.5×10^{10} bytes) of data to Earth. The accumulated record will take the science team years to sift through. Though about half the data had been processed, only 1% of it had been analyzed by the November 9, 1983, press conference where the team presented their "quick-look" results reported here.

When asked if there would be attempts to refill the craft's reservoir with liquid helium carried up by the Shuttle and thereby extend the mission, U.S. IRAS science team leader Gerry Neugebauer of Caltech firmly ruled it out. "Once IRAS dies, it's dead," he said. And this makes sense. After all, IRAS has performed its intended mission — a basic all-sky infrared survey — and to prolong the data gathering will simply prevent the team scientists from getting to work on the data they have already. "You've got to remember we're in the middle of an observing run!" exclaimed a somewhat exasperated Charles Beichman when cornered by a reporter who was pressing him for the significance of some observation. "We haven't had *time* to look at that yet!"

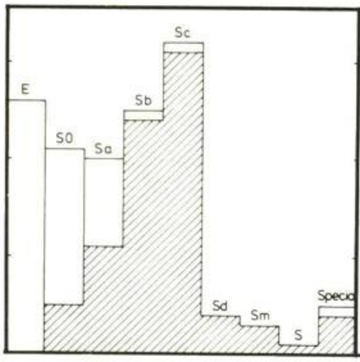
The natural follow-up to a survey craft like IRAS is one that can make extended observations of individual sources using an imaging system with much higher resolution. Two missions are in the works for the mid-1980s: one a cryogenically cooled telescope to be flown on a Spacelab flight in 1985; the other the Cosmic Background Explorer, a satellite to be launched in 1987 to study the Big Bang.

But neither mission counts as the "observatory" needed to pursue the IRAS findings more carefully. Just such a craft is now in the early stages of development — the Shuttle Infrared Telescope Facility (SIRTF, pronounced "SUR-tiff"). According to the design now favored, SIRTF will have a 1-meter cryogenically cooled mirror (IRAS' was 60 cm) and is planned to be launched in the early 1990s. SIRTF is expected to have a sensitivity gain of 100 to 1000 over IRAS and will cover a six-times broader range of wavelengths: 2 μm to 700 μm. In addition, its imaging system will be at least 10 times sharper than that aboard IRAS.

SIRTF might actually ride *in* the Shuttle, but astronomers would prefer that it be a free-flying craft. The problem is that the Shuttle is a very "dirty" or "noisy" ship for a sensitive instrument to be near. It outgasses heavily, and since it is painted white for reasons of thermal control, it reflects a lot of sunlight — as anyone who has seen a Shuttle pass overhead can testify. Additional reflected sunlight hurts the mission because it increases the rate at which a cryogenic craft will use up its supply of coolant and thereby shortens its lifetime. But unlike IRAS, SIRTF is designed to be refueled by the Shuttle, so periodic trips will be made to it by one or another of the four orbiters during its lifetime.

Way spread raggedly several degrees to either side of the galactic plane.

Contrast this with the IRAS views (see page 22). At 12 µm, the bluish glow is due mostly to interstellar dust that has been heated by the light from stars to about room temperature. There is a hint of the Galaxy's ragged naked-eye appearance, but already evident is a strong tendency for the emitting material to line up closely along the galactic plane. Passing to yet longer wavelengths (and cooler temperatures), the distribution flattens out even more. The overall darker appearance of the scans at 25 µm and 60 µm reflects the fact that at these temperatures, little or nothing is contributed by starlight or solar system dust; yet at the same time the wavelengths are too "hot" to see the still cooler interstellar dust very well.



Shaded region shows the number of infrared-bright galaxies and compares them with those in visible light. The message is clear — ellipticals (type E) are free of dust, while spirals (types S) abound in it.

At 100 µm, we enter the realm of the coldest interstellar dust. The IRAS images show a thin line of emission that traces out the galactic plane; you can see it is studded with knots that mark the locations of star-forming nebulae. Since these often contain bright ionized hydrogen gas and young clusters of stars, they are well-known to professional astronomers and backyard telescope users as well. A closer look at the composite image (see pages 20-21) shows that in many places the dust has a wispy structure, providing strong circumstantial evidence of turbulent motions. Although this is especially evident in the central patch that marks the galactic nucleus, Michael Hauser of NASA's Goddard Space Flight Center says, "From this image alone we can't determine whether those wisps are physically associated with the galactic center — or whether something else is going on there. But they are quite intriguing."

Yet this points up a paradox. Why is it that the galactic nucleus — unquestionably a hot and active place — appears so strong at the coldest wavelengths? The answer is that the nucleus is so enveloped in dust that all its more energetic radiation has been absorbed and re-broadcast in the infrared. To use a crude analogy, think of what would happen if you placed a tin can over a 100-watt light bulb. Although the can will shut off all the visible light from the bulb, the same 100 watts of energy will shortly reappear as infrared — as you'll discover if you put your finger on the can after a few minutes! Dust is both extremely opaque and a good insulator (much better than the can), so it will block, absorb, and then re-radiate at cold infrared wavelengths all the high-energy radiation it receives from the active nucleus.

But given all this, why is the Galaxy so broad when seen by eye and so thin when seen by infrared? It comes down to geometry and perspective. The starry sky (as opposed to the dusty sky) contains a great many bright objects that are near us. Therefore, even though they lie relatively close to the galactic plane, these stars *appear* to lie farther from it. The dust, on the other hand, is much farther off and accordingly looks thinner and defines the galactic plane better.

IRAS has also uncovered another, quite subtle feature of Milky Way dust. It appears as a very faint background radiation in the 100 µm band — even at high galactic latitudes north and south, where the effect ought to thin out — and apparently comes from sheets of matter several hundred light-years thick that parallel the galactic plane. Just what this material is remains unknown. The project scientists would like to identify it and map its extent, since it has clear implications for the "missing-mass" problems (see "Galactic Coronas," ASTRONOMY, November 1982). This astrophysical puzzle comes about from the fact that to judge by their internal dynamics (motions and visible mass), spiral galaxies shouldn't exist in the forms we observe, because they simply haven't enough mass to hold themselves together. Yet they clearly *do* exist — and for the past 10 years or so, galactic researchers have been probing with growing concern the question of where the missing mass is.

Once again, dust may offer some clues. The IRAS findings have shown that many galaxies contain more dust than was previously thought. One useful index of a galaxy's dustiness is its ratio of infrared to visual energy output. For example, astronomers say that for M-31, the Great Galaxy in Andromeda, the infrared output is about $\frac{1}{30}$ its visual output. For the Milky Way the ratio is about even (1:1), and for the peculiar galaxy M-82 in Ursa Major, the infrared is four times stronger than the visual (4:1). (Before IRAS, M-82 was the dustiest known.) By contrast, IRAS has turned up some specimens of galaxies that have infrared emissions 10, 20, even 50 times the visual. In fact, such infrared-bright galaxies appear to be more common than those which dominate in the visual!

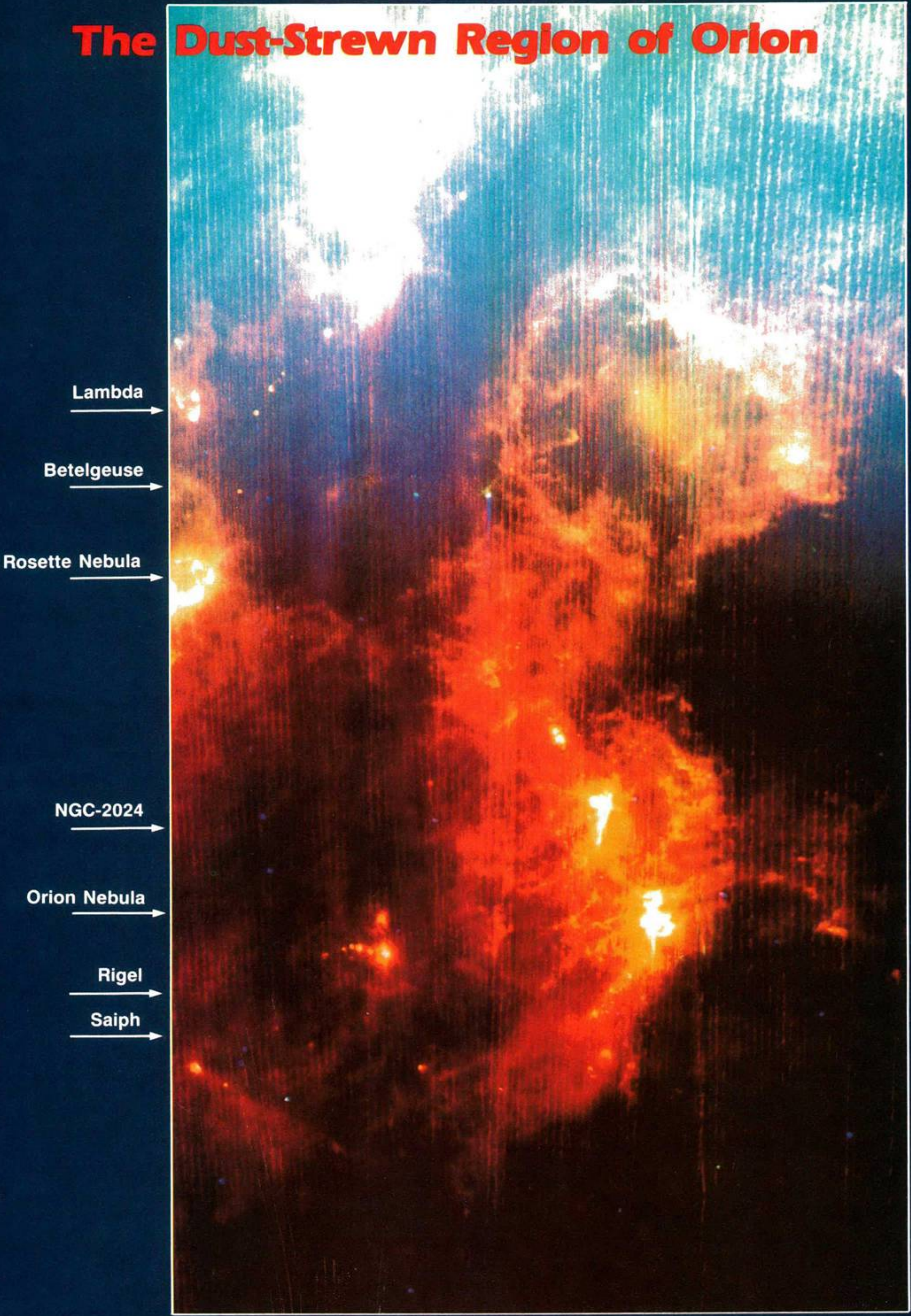
"Away from the galactic plane, IRAS shows that the infrared sky is dominated by galaxies," notes project astronomer Thomas Soifer of Caltech. Ordinary stars are invisible at those wavelengths, Soifer says, adding that "If you were to look at the sky at 60 µm or 100 µm, the vast majority of the 'stars' you'd see would not be stars at all, but rather galaxies at distances of millions to hundreds of millions of light-years." By the time the IRAS catalogue of objects is complete, mission scientists expect to have a list of between 10,000 and 20,000 galaxies that are infrared-bright.

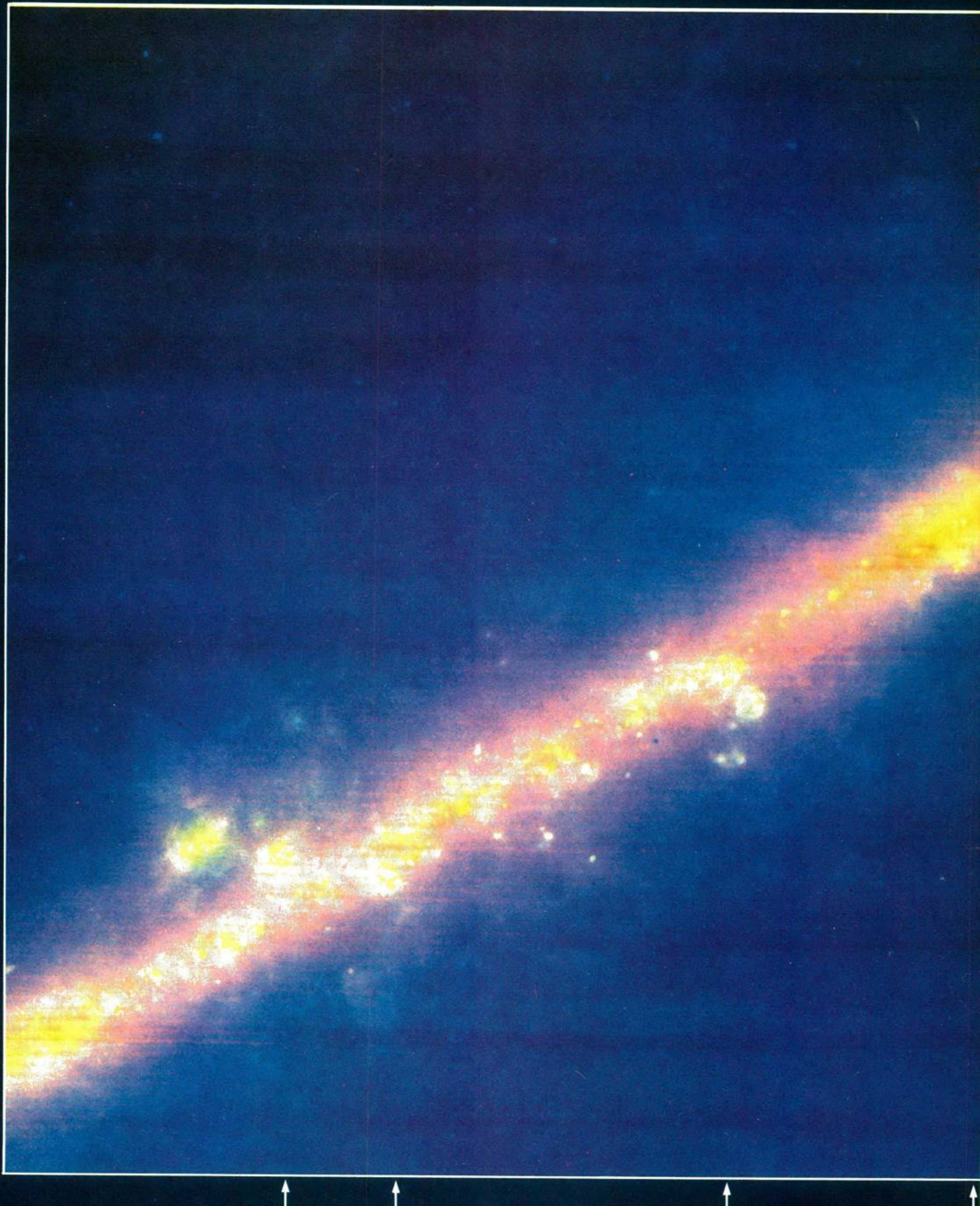
What kinds of galaxies are these? Most are ordinary spirals — just like our Milky Way or M-31. Astronomers have long known that galaxies of this type are rich in gas and dust and undergo constant star-formation. But spirals aren't the whole story; many of the rest of the infrared-bright galaxies turn out to be strange and peculiar objects. Some appear to be colliding or interacting galaxies. Others seem to be suffering explosions or eruptions of some kind. Photographs of such tortured-looking objects have given rise during recent years (more in the popular press than in the scientific literature, though) to notions that the universe is a relentlessly violent place.

But recent ground-based work and the IRAS data hint

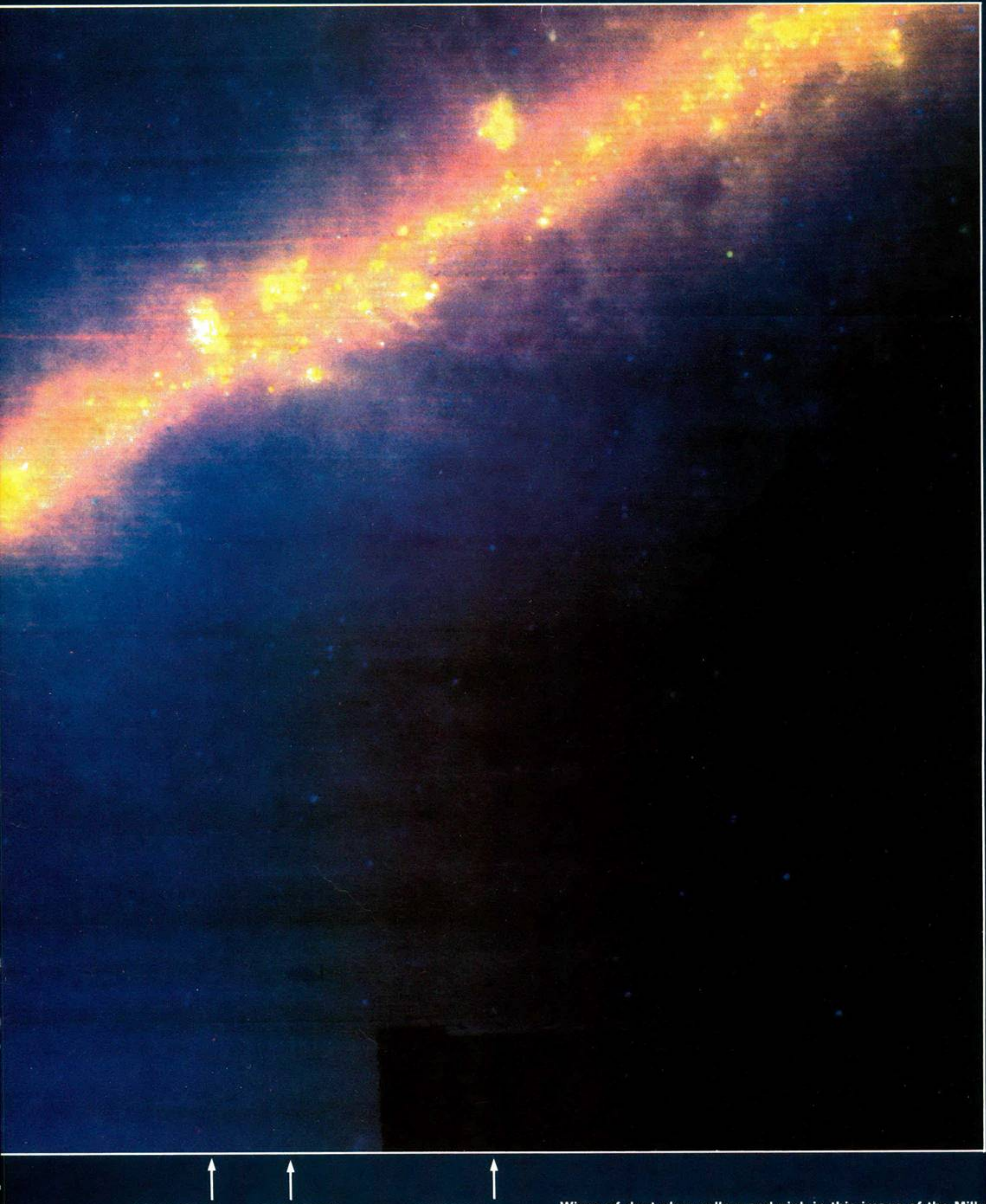
Orion is another region of active star formation. To IRAS, though, the only star that shows up is red-giant Betelgeuse, while all around swirl clouds of dust. The blue haze across the top of the photo is nearby dust lying in the ecliptic. Note the round shell of dust around Lambda Orionis.

The Dust-Strewn Region of Orion

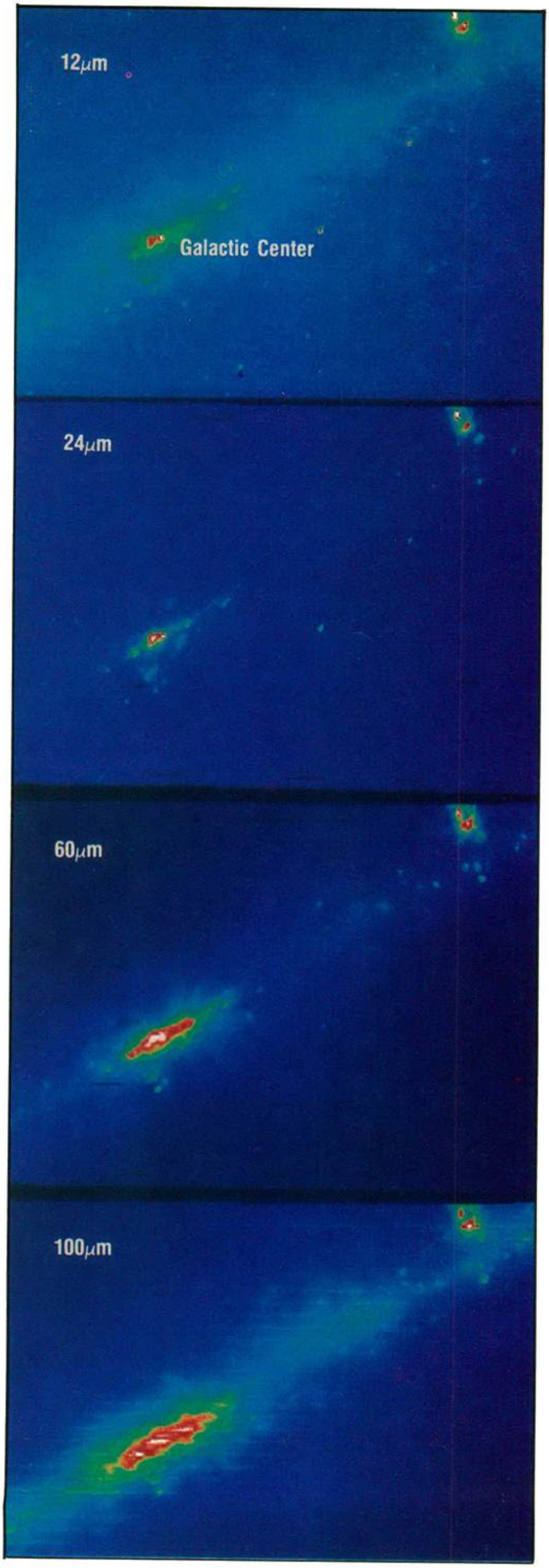

Lambda
Betelgeuse
Rosette Nebula
NGC-2024
Orion Nebula
Rigel
Saiph



M-16
M-17
M-8
Center of the Galaxy



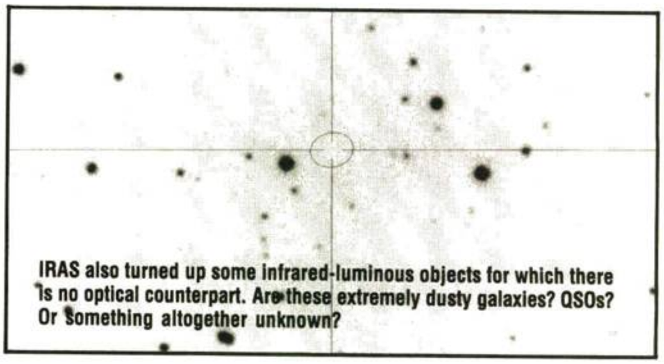
Wisps of dust glow yellow and pink in this image of the Milky Way from Scutum (at lower left) to Norma (upper right). In the middle is the center of the Galaxy; other features are labeled. The temperatures of the dust show up as colors: from blue for the warmest (around room-temperature) to red (around 30°K).



These views of the galactic center show (top to bottom) the dust at wavelengths of 12μm, 24μm, 60μm, and 100μm. The 12μm image shows dust warmed by starlight to about 250°K; that at 100μm shows dust at about 30°K. Notice how much more prominent the galactic center is at the longest (coolest) wavelength. This happens because the dust is blocking the radiation from the core of the Galaxy very efficiently.

that the truth may be somewhat less melodramatic — but very interesting all the same. If these galaxies are dustier than the average spiral, then it is likely that their star-formation rate is also correspondingly higher. "The infrared emission is a measure of the rate of star-formation," says Soifer, "but for the most powerful emitters, we don't really know what the origin of their activity is." One possibility, he adds, is that these are objects like quasars that are hidden in very dusty galaxies.

A few of the infrared-bright galaxies — about 100 in all — can't be seen in the visual at all. Existing long-exposure photos with large telescopes reveal nothing in the most probable locations for these objects, though new post-IRAS work with extra-sensitive detectors may turn up optical counterparts for some of them. As it stands now, though, the scientists can't say if these objects are an entirely new type of object or if they are more-or-less ordinary galaxies that happen to be extra-heavily endowed with dust. The former is a possibility, though a lot more work would have to be done before it could be established. In the latter — and far more probable — case, these objects are still very intriguing. Based on the magnitudes which the photographs have penetrated to, these galaxies must have infrared to visual ratios of at least 100:1. Unfortunately, having only the IRAS data to work on, and having no visual results to compare with, very little can be said about these enigmatic objects — not even how far away they might be.



IRAS also turned up some infrared-luminous objects for which there is no optical counterpart. Are these extremely dusty galaxies? QSOs? Or something altogether unknown?

For now, the IRAS story halts here. These findings represent the cream of the results, as the scientists are just beginning to look at their collected data. What they mean for astronomy is still an unsettled question and will probably remain so for a long time — though it is already clear that astronomy textbooks will need revisions in many areas. But IRAS is really just the beginning. It's a survey — a catalogue — of the infrared sky. In the years to come, as the data are refined, analyzed further, and understood, they will take their place in that small, short list of things we know about the universe. But the most important and precious findings will be the ones we *don't* understand, for these will point the way for future exploration.

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In a galaxy far, far away, it is a dark and rocky night.

A spacecraft winds its way among the asteroids, some spaced only two feet apart. Collision is surely imminent. Gasp. The crew nervously navigates, unable to predict each asteroid's helter-skelter orbital path. Such is the drama of one sequence from *The Empire Strikes Back*, the second of at least seven planned *Star Wars* episodes.

The Empire Strikes Back and many other science fiction films trade accuracy for dramatic effect, treating accuracy as if it could somehow diminish box office income. Astrophysical maxims are willfully abandoned as the moviemakers let drama and action determine the laws of physics, spacescapes, and the physiology of extraterrestrials.

Even the moderately informed spectator would overlook these errors if the fictions portrayed were more engaging than the truth.

But they're not. Three successful films demonstrate that without compromising the finer points of science, profits are possible. Both book and film versions of *2001: A Space Odyssey* generated enormous profits. In the case of Kurt Vonnegut's *Slaughterhouse Five*, the book was more successful than the film, but one would guess that their combined income is nonetheless respectable. *Hitchhiker's Guide to the Galaxy* began as a BBC radio series, then a book and finally a BBC TV series, later exported. Of the three, *2001* tops the list and, as a cult classic, enjoys continuing income from TV sales and repertory cinemas; the other two will probably be modestly revived.

Each production undoubtedly will stand the test of time. Even now, in 1984, only the costumes and set designs of *2001* remind us of its 1968 release date. Moreover, these films assume that the viewer is sophisticated, while other science fiction films apparently adopt the lowest-common-denominator theory, severely shortchanging the intelligent spectator.

Slaughterhouse Five, 2001 and *Hitchhiker's Guide* probably succeed because they approach the audience on multiple levels. At the low end of the spectrum, uninformed viewers are dazzled by the visual splendor of *2001*, caught up in *Slaughterhouse Five*'s black humor, or tickled by the Pythonesque humor of *Hitchhiker's Guide*. At the other end, informed film viewers appreciate each filmmaker's intelligent application of science within a dramatic or comic context and dismiss minor flaws.

But these films are the exceptions. As a rule, Hollywood grossly underserves informed film-goers and radically underestimates their numbers. Another forgotten but growing market is those who perceive films as an opportunity for both education and entertainment. Rather than recognizing new markets, Hollywood insists on the mindless approach from script selection, to production decisions, to final release.

Outer space often becomes a backdrop for the tried and true formula. In *E.T. The Extraterrestrial*, E.T. is anthropomorphized so much that the film is really a story about a boy and his humanoid pet. Both *Star Wars* and *The Empire Strikes Back* are westerns

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pitting white good against black evil. Serving as a subplot, the Princess's relationship with both Skywalker and Solo is sexually and romantically charged. The man-and-his-pet theme thrives with Skywalker's robot assistants, C3PO and R2D2.

Despite an industry filled with such weak offerings, director Stanley Kubrick insists, "If it can be written or thought, it can be filmed." This cinematic axiom is rich with meaning and potential — and Kubrick honors this promise in *2001*.

Kubrick may partly be referring to impressive advances in special effects technology. According to *American Cinematographer*'s 1968 issue devoted to *2001*, Kubrick, Con Pederson, and Douglas Trumbull pioneered several techniques, now staples of special effects technology. During the special effects bonanza of the mid-70s, only refinement of existing techniques was necessary. The development of technology in cinematic history indicates dependency on other media and technology for its own evolution. The inception of cinema borrows from still photography technology. Still backdrops, similar to those used in plays, can show day or night skies, within or without our solar system, as in *Slaughterhouse Five*. Long-established animation techniques may be used to show planet, star, or asteroid movement. Fancy multi-channel sound borrows its technology from advances within both studio recording and home stereo technology. The sound emitted from the descending spaceships in *Close Encounters* effectively elevates the status of spaceship-as-prop to spaceship-as-character whose high profile presence depends on this sound technology.

Remote control technology has been applied to alien representation, most notably E.T. A midget human inside the E.T. costume mobilizes E.T.'s legs, while E.T.'s eyes and mouth are controlled by an elaborate panel of switches and levers off the set. E.T.'s technical credits cite 19 individuals in eight categories including E.T.'s Voice Design, E.T.'s Eyes Design, E.T. Movement Coordinator, E.T. Operator, Special E.T. Movement, and Additional E.T. Effects.

By eliminating worries about technique, only adequate funding stands between an idea and its cinematic representation. However, budgets are apparently not an issue either. By 1983, a budget of $40 million was possible. Spielberg claims that the budget for *E.T.* was less than $11 million, and in 1968 $6.5 million of the total $10.5 million budget of *2001* covered special effects. Hence, research, script choice, and production decisions together represent the weakest links in science fiction film production.

But there's more to it than technique. In most science fiction films, guesswork replaces research. Often what is passed off as science fiction is no more than an Earth drama set in outer space. Add a few buzz words like "warp speed" and "intergalactic" sprinkled like Reese's Pieces throughout the script, a ho-hum replica of Earth skies on a clear night, and the spectator won't know the difference.

What passes for research is lip service. Although a technical consultant is listed in the closing credits of *Close Encounters of the Third Kind*, the production itself suggests that only a few isolated segments were offered for consultation.

If "under-researched" characterizes *Close Encounters*, then "over-researched" describes Kubrick's efforts in *2001*. After Kubrick confirmed Arthur C. Clarke's collaboration, he went on to contact many other academics and researchers from NASA, the Jet Propulsion Laboratory, General Dynamics Corp., Goddard Space Flight Center, Honeywell, Inc., IBM, Lick Observatory, Lowell Observatory, and the U.S. Weather Bureau. The experience prompted Kubrick to say, "I am greatly disturbed by the barrier between scientific knowledge and the general public." And the film keeps Kubrick's 1966 promise: "Everything possible would be done to make each scene [in *2001*] completely authentic and to make it conform to what is known to physicists and astronomers." Indeed, Kubrick's representation of zero gravity prompted cosmonaut Alexei Leonov to say, "I feel I've been in space twice," after he saw *2001*.

Unlike Kubrick, the creators of *Hitchhiker's Guide* apparently have strong backgrounds in physics, mathematics and astronomy — knowledge that they incorporated into the script. The central premise in *Hitchhiker's Guide* is simple: An alien journalist has been masquerading on Earth as a human for 15 years before the first episode begins. His assignment is to update a book entitled *Hitchhiker's Guide to the Galaxy*. When the alien is found out, he informs Arthur Dent, his earthling friend, that his research will result in the descripton of Earth being changed from "harmless" to "mostly harmless." Helplessly, Arthur says, "That's *it*!?" As so often happens in *Hitchhiker's Guide*, a tiny exchange speaks volumes about cosmology, indicates knowledge or research, is entertaining, and costs very little for great effect.

Slaughterhouse Five illustrates that the terms "scientifically accurate" and "low budget" can be credibly uttered in the same sentence. The last quarter of the film is located on a fictitious planet called Tralfamadore, and is so inexpensively executed that one is reminded of just how vast and varied astrophysical knowledge is, even though the margin for scientific error is greater in *Slaughterhouse Five* than in either *2001* or *Hitchhiker's Guide*.

Dialogue is another powerful yet inexpensive device employed in both *Hitchhiker's Guide* and *Slaughterhouse Five*. For example, an invisible Tralfamadorian tells Billy Bishop, "We can see you, but you can't see us; we live in four dimensions." Hey, so do we! Imagine the cost of the special effects Hollywood might have poured on — but what for?

Viewer deprivation is perhaps most obvious in run-of-the-mill spacescapes. Anyone who checks photos from unmanned probes often concludes that filmmakers haven't. Furthermore, few filmmakers acknowledge and obey physical laws. In *2001*, spacecraft movement always obeys parallax; the farther away an object, the slower it appears to move. Dwarfed by a giant spacescape, *2001*'s tiny vehicles move very slowly indeed. Some other filmmakers completely abandon natural laws. In *Star Wars*, *Star Trek*, and *The Empire Strikes Back*, space vehicles zoom past the camera at "hyper speed" regardless of how small they

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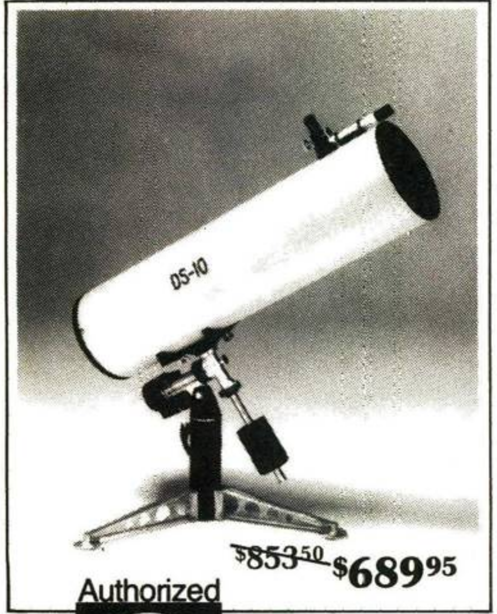

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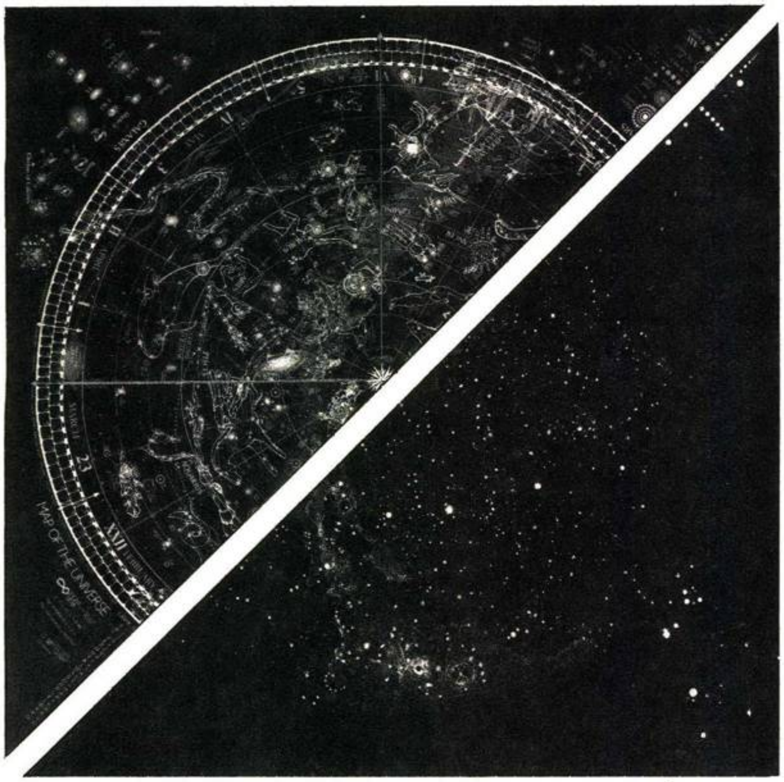

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are relative to the spacescape. Apparently, these filmmakers only know that a spacecraft travels faster than an aircraft, regardless of spectator perspective.

Of course, the degree to which network and studio executives control scripts and shooting plays a significant role in the intelligence, subtlety, and accuracy of productions. Kubrick states that MGM acted like a silent partner by allowing him complete control over *2001*. On the other hand, Carl Sagan quotes Harlan Ellison regarding *Star Trek*'s inception: "Even such sedate biological novelties as Mr. Spock's pointy ears and permanently querulous eyebrows were considered by network executives far too daring . . . such enormous differences between humans and Vulcans would only confuse the audience . . . and a move was made to have all physiologically distinguishing Vulcanian features effaced."

Subtleties through inferences, ellipsis, or stating a point only once are also believed to "confuse audiences." Yet *2001*, with only 40 minutes of dialogue, tells us more by implication than by on-screen evidence. For example, many critics complain that *2001*'s script is uninspired because the characters speak in clipped sentences with mostly monosyllabic words. Perhaps Kubrick opted for this speech style in anticipation of the shift away from "literary" literacy to visual and computer literacy. Video displays in *2001* register complex coded messages or moving three-dimensional drawings. Often a character watches eight screens simultaneously, with each screen changing every 15 seconds. Not only does Kubrick correctly anticipate changes in man's relation to machines, but he accurately predicts computer dependency in future space missions — already evident now, in 1984.

Different environments and points of view within the universe are another spacescape aspect often not employed. However, in *Hitchhiker's Guide*, multiple suns illuminate day skies from a foreign environment's perspective and references are made to pink skies elsewhere. We see Earth from the Moon and close-ups of other planets and natural satellites in *2001*. Astronomical times and distances are also acknowledged; Bowman and Poole watch a BBC broadcast about their mission to Jupiter on *Discovery*. The reporter states that it takes seven minutes to reach their craft. In *Hitchhiker's Guide*, Arthur asks about a distance and gets an incomprehensible answer followed by, "That's a one followed by two pages full of [zeros]." Perhaps "audience confusion" precludes mentioning time and distance in other science fiction films.

The less informed viewer who sees *Slaughterhouse Five*, *2001*, and *Hitchhiker's Guide* before he see films like *Star Wars*, *Star Trek*, and *E.T.* intuitively recognizes the faults of the latter films. Although he may be unable to articulate their specific errors, he will, nonetheless, be certain that something is amiss.

We see, for example, *Star Wars* characters exploring a remote planet's surface wearing street clothes and hospital oxygen masks. "The ground sure feels strange here," one character tells another. Who could believe it? Compare that to the Tralfamadorian's explanation to Billy that he had best stay inside his Earth atmosphere simulation bubble: "The atmosphere here is largely made up of cyanide."

With such a diversity of cosmological theories and hypotheses about alien intelligence offering vast, built-in artistic license, it is amazing that any filmmaker would need to manipulate or distort well-known and understood natural laws.

For that matter, so little is known about alien intelligence that they have a completely free hand when it comes to aliens. Most scientists scoff at the possibility that alien physiology would have anything in common with human physiology. In *Cosmos*, Sagan posits an interesting jovian scenario. Since Jupiter is gaseous, a hypothetical descent into the jovian atmosphere would begin with dense fog, cloud, and gas. Farther down, there would be more congestion and muck until one "lands." Landing on Jupiter is difficult to discern because the slush just gets slushier. Sagan, following Arthur C. Clarke's original suggestion, proposes that one type of intelligent life would be "floaters," hot air balloon organisms suspended high above the jovian "surface." Sagan's example implies that evolution in a wildly different environment may be quite different from the results of the evolution of life on Earth.

Interestingly, alien beings are visually absent in *2001* and *Slaughterhouse Five*, but their absence suggests unimaginable possibilities. Hollywood aliens have uniformly been visual disappointments; their capacities are often less than a thousand years ahead of ours. Moreover, they visit us more often than the more likely scenario of us visiting them. And Hollywood's aliens almost always land at night and in populated regions of the U.S. If these aliens have eyes and vision like ours, wouldn't they prefer the sunward side of our planet for landing?

Alien value system differences are nearly guaranteed, yet seldom exploited. A Tralfamadorian tells Billy, "We've visited 31 inhabited planets and have studied 100 more and nowhere but on Earth do they discuss 'free will.'" Yet, most films since *Slaughterhouse Five* have ignored the entertainment possibilities of whimsically pointing a finger at ourselves and our collective foibles.

Familiar and desirable human traits characterize E.T. — gentleness, wisdom, and vulnerability. Worse still, Steven Spielberg shows us that E.T. gets drunk, eats Earth food, but doesn't like potato salad(!), and learns broken English within weeks. E.T.'s paranormal traits include a healing forefinger, a luminescent chest, and the ability to levitate bicycles many feet above the ground. Doctors try to measure Elliot's and E.T.'s vital signs side by side in computer graphics. Wouldn't the drama have intensified if E.T.'s reading had remained blank?

E.T.'s strong kiddie appeal accounts for the film's overwhelming commercial success. However, technological literacy and the national I.Q. are steadily increasing. If *2001* is for adults and *E.T.* is for kids, levels of sophistication between the two are rarely exploited. Since visual literacy is increasing, film and TV may supersede reading. This may mean that only non-fiction television like *Nova* or narrow-cast science and science-fiction will communicate the nuances and subtleties of the universe.

Lowest-common-denominator science fiction films may continue indefinitely, especially if box office income remains high. But if it does, we will never learn through cinema that the universe, as J.B.S. Haldane wrote, "is not only queerer than we suppose, but it is queerer than we *can* suppose."

Carol A. Rutter
Montreal, Quebec

The author wishes to thank Frank Stark for his patient advice in preparing this article. Carol Rutter is an executive of the Film Studies Association of Canada and a regular contributor to Cinema Canada *and other Canadian publications.*

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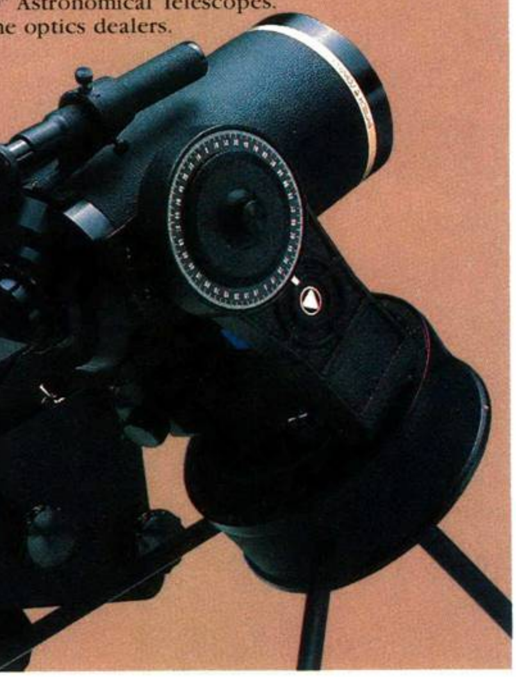

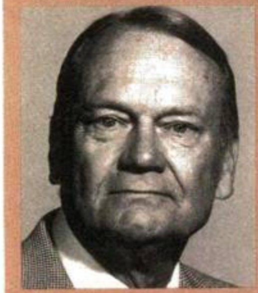

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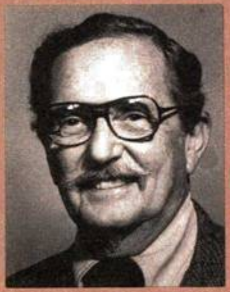

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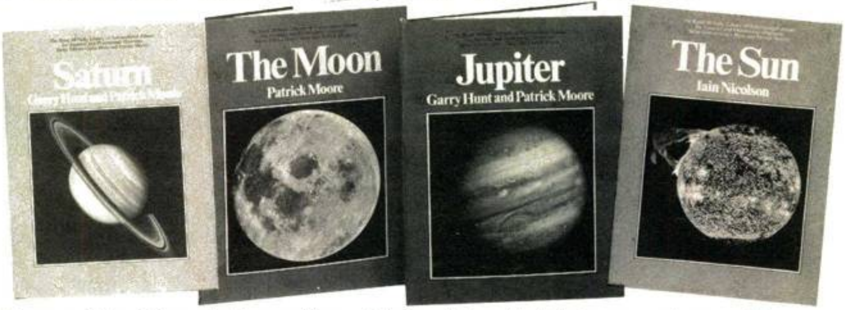

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Film Type (35mm unless marked)	Exposures	Price
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VR1000, fastest of all, color negs	12	$12.95
5072, color slides from negs	36	$6.95
D-19 B&W Developer, 1 gal.		$5.95

ASTRONOMY In Focus

Methane Ice Sinks

Sir / "A New Mission to Saturn," by Michael Carroll (December 1983), provided a fascinating glimpse of future explorations of the saturnian system. Unfortunately, however, Carroll's water/ice/steam analogy for the methane on Titan's surface is contrary to the physical chemistry of these two substances. Consequently, so does his painting.

The surface of the Earth is not at the triple point of water, which is 0.01° C and about 0.006 atmosphere pressure; nor is the surface of Titan at the triple point of methane, which is about −180° C and 0.1 atmosphere pressure. The temperatures are about right, but the pressures are much too low. Conditions on Earth and Titan, however, are such that the three states (solid, liquid, and gas) of water and methane respectively can exist under conditions not too far removed from those at the surface of the two planets, *but not in the same place at the same time* — which is what a triple point implies. (They may, however, coexist at higher altitudes.)

The other speculation draws too close an analogy between methane and water; it concerns the existence of ice floes and glaciers. The fact that water ice floats on liquid water makes water one of the most unusual substances known. So far as I know, only two other substances (bismuth and antimony) share this property; methane does not. The solid form of almost every substance that melts without decomposing — including methane — sinks in the liquid form.

Thus, a methane ocean, unlike a water ocean, would freeze from the bottom up and, once frozen, would be almost impossible to melt, except for a thin layer at the surface. It could not have the same moderating effect on Titan's climate that a water ocean has on Earth.

For the same reason that water is denser than ice, terrestrial glaciers can flow. The pressure generated by their weight tends to melt them at the bottom and sides and so they can move. Methane glaciers, in the event that they formed at all, would not melt under pressure. Freezing even harder, they would lock themselves in place and the glacial flow patterns shown in Carroll's painting would not occur.

D.M. Graham
Vancouver, British Columbia

The Other Side. . .

Sir / In your December 1983 issue were two articles spreading the almost religious belief that life can easily be created in nearly any environment. Linda J. Strand concludes that the Viking landers' results were not negative but a "maybe." If one considers the results of the Viking lander data as a whole, one must conclude that there is no life on Mars. And the article on life on Europa was an example of science fiction.

It is time that we stop engaging in inconsistent speculation about life everywhere and begin to proceed in a logical, scientific manner. As an inorganic chemist, I would gladly have swapped all the worthless data from the Viking life experiments for a simple sodium analysis of the martian soil.

Joseph E. Wreen, Jr.
Atlanta, GA

Don't Neglect Data Analysis

Sir / Over the past few years, much effort has been devoted to promoting planetary exploration. Lately, it seems like efforts are subsiding. Some battles — such as the Venus Radar Mapper — have been won, and the tide is swinging our way with the tentative approval of the Mariner Mark II and other "economical" spacecraft.

However, there is still one point that deeply concerns me. While the future of planetary probes is looking up, the future for the analysis of data — determining what all those pretty pictures mean — is still uncertain. It has been estimated that within the next couple of years the funding for data analysis will drop to 50 million dollars, a sum much too low for such an important task. I put it to you: What good is gathering data when there are no funds for determining what we have discovered?

Scott A. Thurlow
Port Hope, Ontario

Landsat's Earth Photos

Sir / I was totally wiped out by the Earth photos in your November lead feature. They're terrific! I live in San Francisco and although I haven't yet found our house in the cover photo, I'm still looking because I just know it's there! Now a question: can I get a print or a poster of the cover?

Doug Blackmont
San Francisco, CA

Dear Mr. Blackmont (and the dozens of other people who wrote in, too!) / We don't have any posters of those photos, but you can buy copies of them from the U.S. Geological Survey's EROS Data Center in Sioux Falls, South Dakota (their zip is 57198). Write to them for a copy of their price sheet. This lists how much they charge for a given-size image and breaks down the prices for black and white or color, print or transparency format. When you know which image(s) you want, send them the image number, a photocopy of it, or the date it was taken. This will help them find the photo you want.

Neutrino *Pressure:* The Final Chapter

Sir / Guy Rodrigue (In Focus,

September 1983) has asked how massless particles can produce pressure. David Reiskind (In Focus, January 1984) replied that, since mass and energy are equivalent, photons must have mass and momentum. However, the energy of a particle with rest mass m and momentum p is:

$$E = (m^2c^4 + p^2c^2)^{1/2}$$

Since a photon has a zero rest mass, its momentum is $p = E/c$. Hence, massless particles are perfectly capable of transferring momentum, inducing pressure.

Daniel James Mearns
University of California, Irvine

Errors in Time

Sir / There are two errors in your article, "Clocks and Calendars for Astronomy," in the January 1984 ASTRONOMY.

The first is your statement that Caesar created seven 31-day months, four 30-day months, and one 28-day month. Caesar's calendar, as introduced effective 45 B.C., contained *six* 31-day months, *five* 30-day months, and a February with 29 days. One of the 31-day months was July, which he had named for himself. The month we now call "August" was then a 30-day month called Sextember (i.e., sixth month). After Augustus (the first man to use the title Emperor) succeeded Julius Caesar, he became jealous of the fact that one of the calendar months was named for his uncle. Accordingly, he arranged to have September renamed August for himself and, to further equalize things, robbed one day from February so that his month would also have 31 days.

The second is the statement that the Protestant countries generally rejected the Gregorian calendar until 1752. It is the frequently seen error of equating England with the Protestant world. Rather than being in the forefront in 1752, old England was bringing up the rear. Most of the other Protestant states, including Holland, Denmark, and virtually all of the German states, had adopted the Gregorian calendar in 1699, just in time to avoid having another leap year in 1700 and falling yet another day out of line. In 1752, when Great Britain and the British Empire (plus Sweden) finally switched to the Gregorian system, the entire Western European world was finally all back on the same calendar after a lapse of 170 years.

By the way, you might have mentioned that the time zone map shown on page 52 represents the zones pretty much as they are today, and not the way they looked when first established in November 1883. The Eastern and Central zones have crept much farther west since their initial founding. Your map shows Indiana in the Central Time belt, but all of that state except for about six counties near Chicago switched over to Eastern Time about 1967, when Congress adopted the Uniform Time Act.

Fred C. Davis, Jr.
Baltimore, MD

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Behind the Scenes | Our New Close-up Map

For more than ten years, we've run a Constellation Close-up map every month in the Backyard Astronomer. This map has changed quite a bit over the years as we have tried to tailor ASTRONOMY to fit your needs. Originally the map was plotted with black symbols on a white background. Then for several years it ran as two photos every month. One was a negative image; it had black stars on a white background, with everything labeled. The other was in color. We later put the labels into the color picture and dropped the second map.

I am sure that each of these maps had both adherents and detractors. For example, at star parties I have seen serious observers with collections of every Close-up map we've ever run, neatly sandwiched in plastic in a notebook. We've also gotten occasional nasty letters from people who can't find anything with them and blame it on the charts. Our own feeling is that the old maps were "cluttered" — that the faint background stars tended to be distracting and the photo didn't translate into a night sky viewed through a typical finder telescope. So we set out to "clean it up."

There's a lot to be said for plenty of faint stars in a star chart, especially if you're trying to find exceedingly faint deep-sky objects from a dark site. We were tempted. But most of you, as the title of the department implies, observe from your own less-than-perfect backyards. In the end, we settled on 6.5 as the most useful and practical limiting magnitude for our new charts, all things considered.

It took about six months to prepare the new maps. We developed software for computer-plotting stars and made hundreds of experimental maps. We explored many possibilities, such as including all stars to ninth magnitude. In the end, we opted for white stars on a dark background as producing the least glare, kept the bright stars fairly small, and selected colors that look good and remain readable under both white light and dull-red flashlight illumination. We chose a scale that will necessitate splitting a few of the larger constellations into two parts and including more than one constellation in others, but it displays most constellations well.

And now we're pleased to be able to bring you a new close-up of each major constellation, in its turn, in a clear and useful fashion.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

Gazer's Gazette

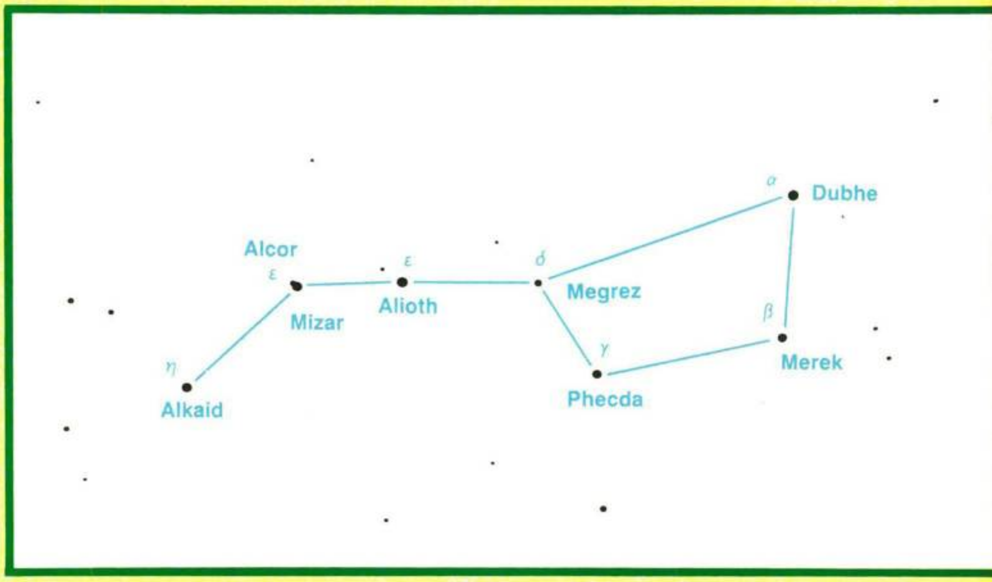
Probing the Constellations of Spring

by Earle F. Dodds

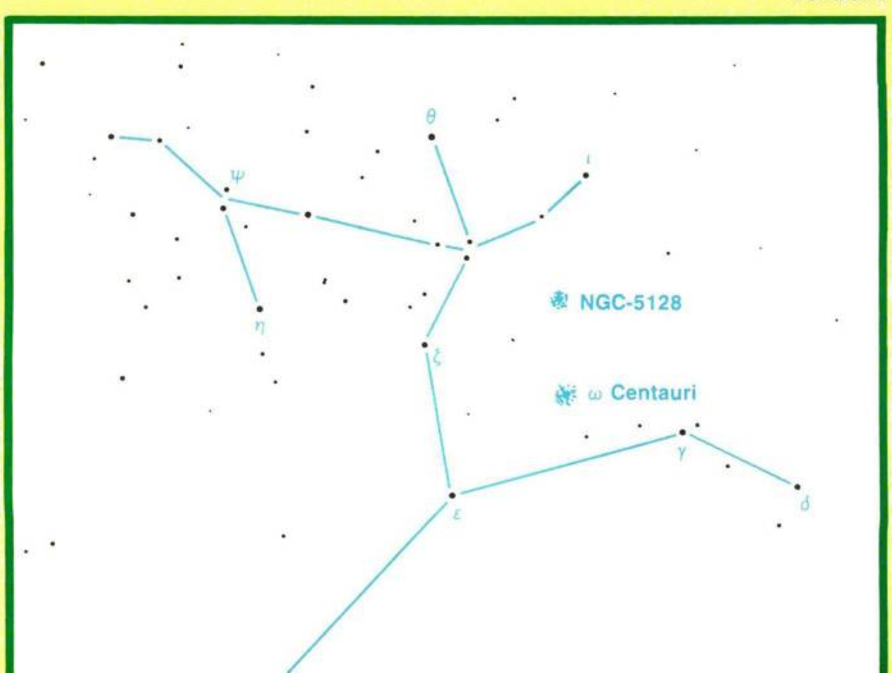
Back in December, with the help of my article "Exploring the Winter Constellations," you had the chance to learn about the sights found in the winter sky: the gleaming Pleiades cluster, Orion's star-studded belt, Gemini's twin bright stars Castor and Pollux, and so on. Now it is time to dust off your chaise longue and ready your binoculars, for the evening sky has brought a new set of constellations, harboring new treasures and waiting for your inspection. And that bitter cold of winter, which almost convinced you not to look at the stars at all (gasp!), has given way to bearably warm evenings that make observing a comparative pleasure.

It's 9:00 p.m. on March 1. You're outside, bundled up in a blanket, with a hot cup of coffee. As you look westward, stars of the late fall sky are setting below the horizon. The head of Cetus is still visible, but the Great Square of Pegasus has sunk below the horizon, not to return until several months pass. Part of Andromeda is visible; the chained princess weakly arches upward in an attempt to retain her position. The galaxy M-31, now only a few degrees above the horizon, appears as a soft glow only to sharp eyes. The diminutive constellations Triangulum the Triangle and Aries the Ram float below the rich winter Milky Way, which is still painted across the sky from Cassiopeia in the north to Puppis in the south.

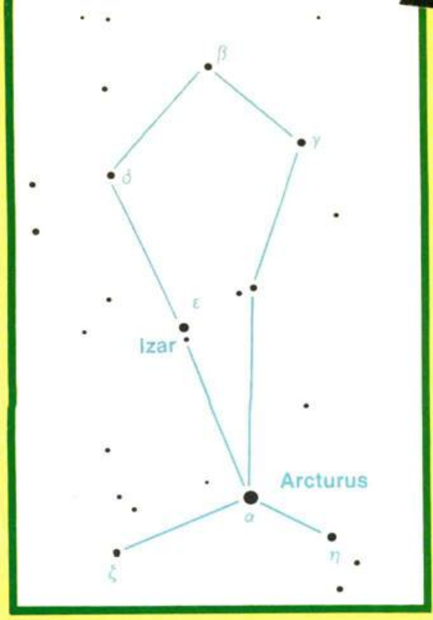
Many of the features of the winter sky that we looked at in December are again visible: Orion the Hunter holds his club and shield high and his sword — composed of the Great Nebula, M-42, and two bright stars — shines with a misty green light. *Binoculars* show the nebula positioned between two tiny groups of stars. Beside Orion is the rather bleak constellation Monoceros the Unicorn, composed of many faint stars. Below Orion lies the striking constellation Canis Major — the Large Dog — dominated by −1.4 magnitude Sirius (Alpha [α] CMa), the brightest star in the sky. Almost directly south of Sirius is the fine binocular



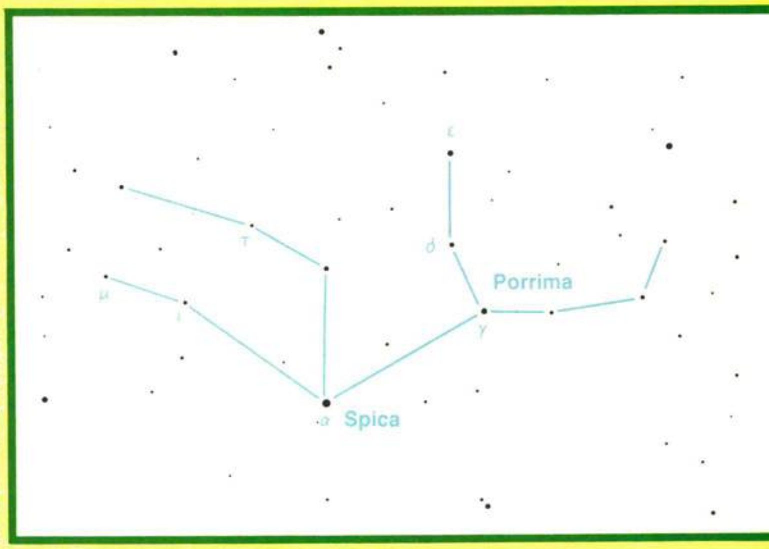
Ursa Major's bright core asterism is known as the Big Dipper and is the most recognizable feature of the spring sky. Can you see both Mizar and Alcor with your naked eye?



The bright blue-white suns of Centaurus sparkle low in the southern sky during most of spring. Binocular observers can enjoy viewing galaxy NGC-5128 and globular cluster ω Centauri.



The constellation Bootes holds the yellowish beacon Arcturus, the fourth brightest star in the sky.



Virgo's main attraction is the blue-white star Spica; its hundreds of dim galaxies require a telescope for viewing.

star cluster M-41, a group of faint stars riding the Galaxy together, bound by mutual gravitation. Above Orion's upraised club lies Taurus the Bull, chiefly made up of the bright V-shaped star cluster the Hyades — found in the same line of sight as the bright orange star Aldebaran (Alpha [α] Tau) and the same area of the sky as the dazzling blue-white dipper-shaped Pleiades cluster. Most people count six or seven stars in the Pleiades with their naked eye. How many do you see?

Infringed upon by the mighty bull's horns are Gemini the Twins and Auriga the Charioteer, both large bright groups of stars that contain open star clusters. Auriga's dominant feature is its alpha star, Capella, the sixth brightest star in the sky. The constellation is formed in the shape of a wide pentagon and contains the binocular star clusters M-36, M-37, and M-38. Gemini contains two bright stars, Castor and Pollux, each of which represents one of the twins' heads. At their feet lies the huge bright cluster of stars dubbed M-35, visible as a grainy patch to the naked eye on dark nights.

But all of these figures rightly belong to the winter sky, when they are most prominent. Tonight we'll study the spring constellations, looking away from the plane of the Milky Way and out toward the realm of the galaxies, the hole in the sky where we look at the deepest parts of the universe. The bright stars forming the spring constellations, however, are all relatively "local" Milky Way objects making their way around the Galactic disk. Dominating the scene, high overhead in the north, is the bright figure of the Big Dipper, the major component of the constellation Ursa Major, the Great Bear. Eight stars are members of the Big Dipper, perhaps the most commonly known asterism: Dubhe (Alpha [α] UMa), Merak (Beta [β] UMa), Phecda (Gamma [γ] UMa), Megrez (Delta [δ] UMa), Alioth (Epsilon [ε] UMa), Mizar (Zeta [ζ] UMa) — and its companion Alcor, which lacks a Greek letter designation — and finally, Alkaid (Eta [η] UMa). All of these bright stars are members of a cluster called the Ursa Major Moving Group, a loose assemblage of stars about 75 light-years away from us. Scanning this region with binoculars presents some fine views of typically bright, bluish-white suns. The Big Dipper — now presented with bowl turned down so as to spill its contents — is particularly renowned for the fact that two of its stars, Dubhe and Merak, point toward Polaris, the star closest to the north celestial pole, the imaginary point directly over the Earth's north pole. High above the Dipper's bowl are two bright galaxies — M-81 and M-82 — which can be glimpsed with a good pair of binoculars on dark nights.

Just east of Gemini is the constellation Cancer the Crab, the fourth zodiacal constellation. This is a faint, inconspicuous group of stars, which does little more than occupy the space between the Twins and Leo the Lion. Cancer does have the distinction, however, of harboring a fine naked-eye Messier star cluster — M-44, also called the "Beehive" because of its likeness to a swarming group of bees. Before the days of light pollution and meteorology, the Beehive served as a weather indicator. If you could see it, there would be no rain; if you could not see it, rain would come. It was as simple as that!

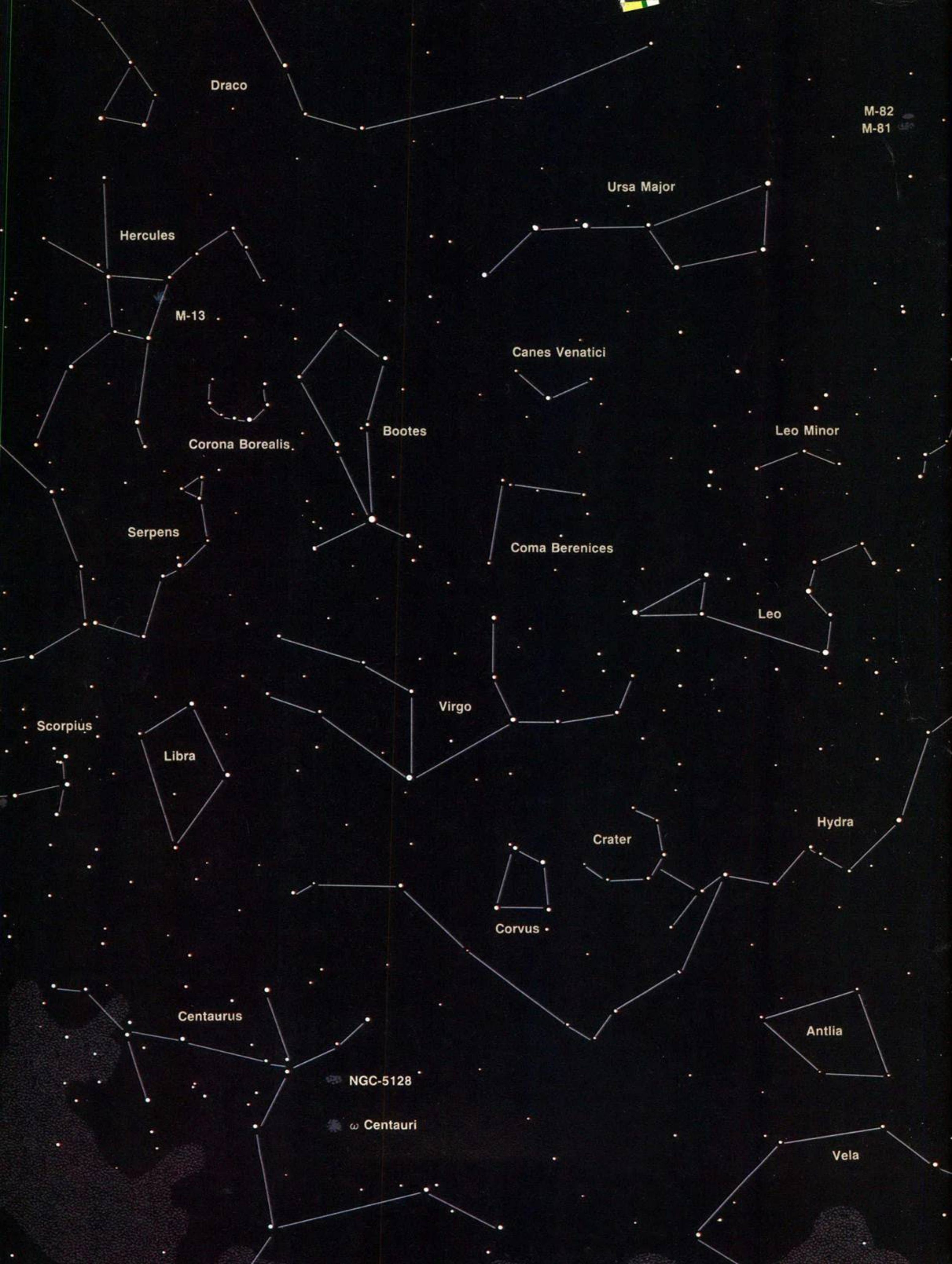
To the east of Cancer is Leo the Lion, a zodiacal constellation that provides no special binocular views, but contains a large number of relatively bright stars. Its basic form is a small triangle connected to a sickle — a backward question mark. Its brightest star, Regulus, forms the base of the sickle and its second brightest star, Denebola, marks the end of the triangle. Although Leo is a telescopic hunting ground for galaxies, the constellation deceptively appears rather barren to those unequipped with a telescope.

Over to the eastern horizon the bright star Arcturus is visible, still low in the sky. Even so, it is conspicuous because Arcturus is the brightest star north of the equator and the fourth brightest in the entire sky. Only Sirius, Canopus, and Rigel Kentaurus are brighter, and they all lie south of the equator. Arcturus has a special relationship with the Big Dipper, whose handle "arcs to Arcturus." Extending the curve takes us to the bright star Spica in Virgo the Virgin. Thus the Big and Little Dippers, Arcturus in Bootes, and Spica in Virgo are all connected through lines of the imagination. Bootes the Herdsman is a fairly bright group of stars nearly shaped in a diamond. Virgo the Virgin is an irregularly structured group of bright stars, silently hiding thousands of faint galaxies behind its glitter.

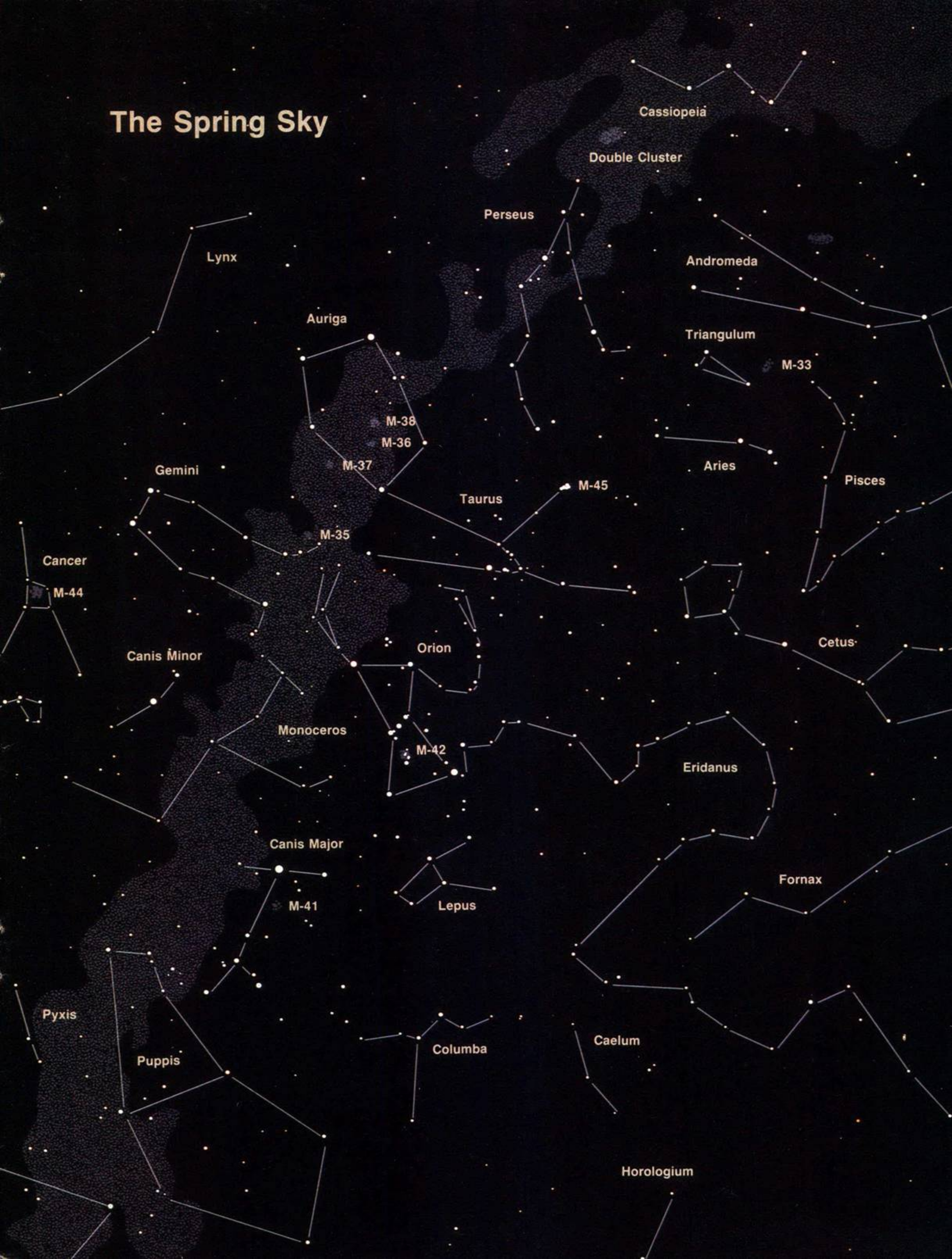
Between the Big Dipper and Bootes is the small group of stars known as Canes Venatici, the Hunting Dogs. It is a constellation of little interest, containing virtually no sights for binocular observers. This is not the case with nearby Coma Berenices, Berenice's Hair, which is home to one of the largest of all star clusters, the Coma Berenices star cluster (Mel 111). The Coma star cluster is an enormous group of bright stars that makes for a fine binocular scan. Larger than the Pleiades or the Beehive, it contains many blue-white stars arranged in an irregular three-tiered branch.

Stretching from south of Cancer all the way down to below the Virgin is a long, snaky constellation called Hydra the Water-Serpent. This mythical monster surely causes the Crab to snap its claws and the Lion to growl aloud in defense as it waits to attack. Apart from being a long chain of moderately bright stars, Hydra is not well known or special, though its brightest star — Alphard — shines brightly almost directly south of Leo. This constellation takes up an extensive amount of sky, one of the largest for any group of associated stars.

Connected to the Water-Serpent is the small group of stars known as Crater the Cup. The brightest star in this constellation is Alkes, a 4.2 magnitude sun — so to the naked eye Crater is almost nonexistent. Its neighbor, Corvus the Crow, is much brighter, consisting of three third-


Draco
M-82
M-81
Ursa Major
Hercules
M-13
Canes Venatici
Bootes
Leo Minor
Corona Borealis
Serpens
Coma Berenices
Leo
Virgo
Scorpius
Libra
Hydra
Crater
Corvus
Centaurus
Antlia
NGC-5128
ω Centauri
Vela

The Spring Sky


Cassiopeia
Double Cluster
Perseus
Lynx
Andromeda
Auriga
Triangulum
M-33
M-38
M-36
M-37
Gemini
Aries
Pisces
M-45
Taurus
M-35
Cancer
M-44
Orion
Cetus
Canis Minor
Monoceros
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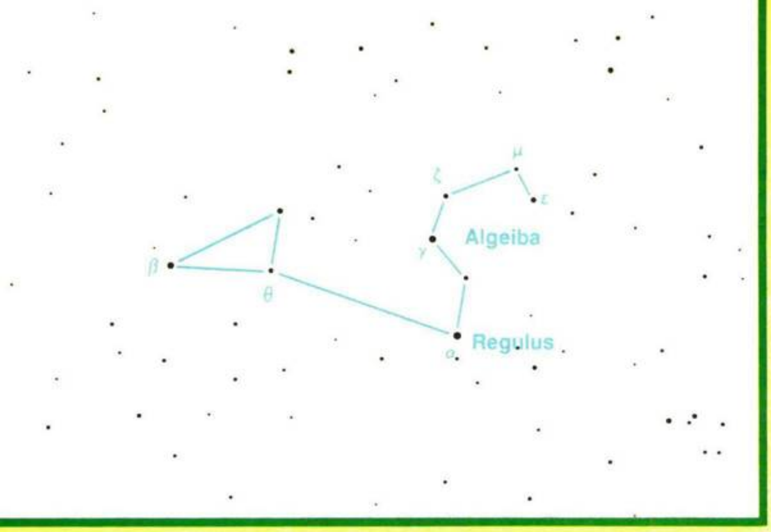
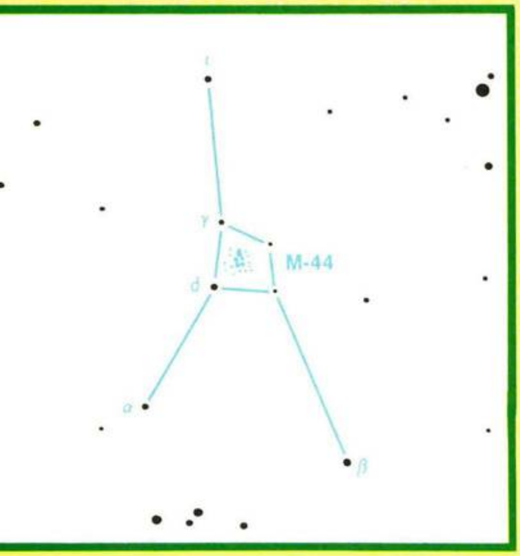
Eridanus
Canis Major
Fornax
M-41
Lepus
Pyxis
Caelum
Columba
Puppis
Horologium

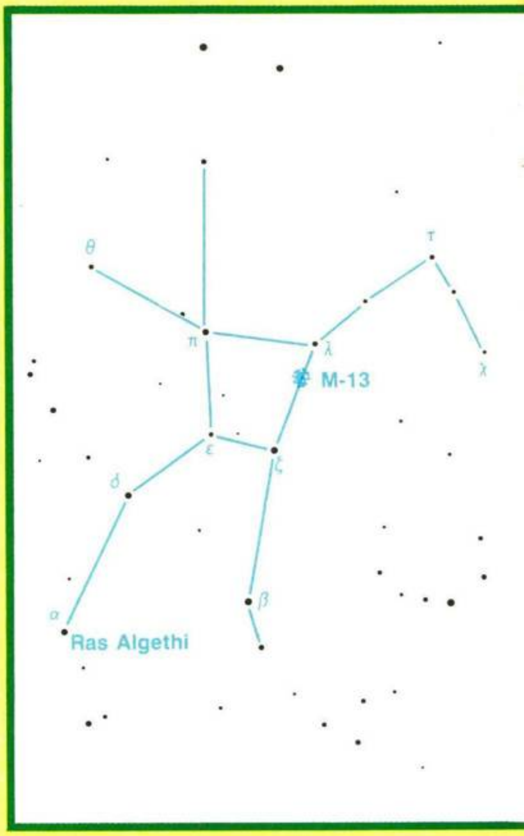


The bright backwards "question mark" is instantly recognizable as Leo the Lion's head and mane. His hindquarters are formed by a triangle of stars including Denebola.



Dim and elusive in its spot between Gemini and Leo, Cancer the Crab has no stars brighter than magnitude four. It does hold M-44, the Beehive cluster, one of the largest and most impressive open star clusters in the heavens.

Hercules is a late spring constellation that marks the coming of the brilliant summer Milky Way. Its brightest star, Ras Algethi, shines at magnitude three. M-13, the Hercules cluster, is second only to Omega Centauri as globular clusters go.



magnitude stars and one fourth-magnitude star. Its form is the brightest recognizable feature south of the sprawling form of Virgo.

Hanging high overhead to the north, a twisting pattern of dim stars suspended above the Dipper, is the extensive form of Draco the Dragon. This huge group of stars wraps three quarters of the way around the north celestial pole, bounded by the constellations Cepheus, Cygnus, Lyra, Hercules, Bootes, Ursa Major, Ursa Minor, and Camelopardalis. Its brightest stars form the head of the Dragon, a small group of four stars of magnitudes 2 and 3. The alpha star of Draco is called Thuban. It is historically famous for being a past — and future — pole star. About 2750 B.C., the north celestial pole lay near this star; due to precession of the equinoxes, its position has since changed to near Polaris. On a dark night, see if you can trace the full body of the Dragon as he gracefully spins about the pole.

Directly below the Dragon's head is the constellation Hercules the Strongman, a group of relatively bright stars marked by its familiar keystone-shaped asterism. The keystone is made up of third and fourth-magnitude stars; inside it lies one sixth-magnitude "fuzzy star" — M-13, the Hercules Cluster, one of the finest examples of a globular star cluster visible from the northern hemisphere. On a dark night it is barely visible to unaided eyes, and it is a fine sight in binoculars, appearing as a misty patch of light. Sandwiched between Hercules and Bootes is Corona Borealis, the Northern Crown, a ragged curve of faint stars of little interest. East of Hercules is Lyra, a tiny group of bright stars including dazzling blue-white Vega, a 0.0 magnitude star that ranks fifth brightest in the sky.

Below Hercules lies Ophiuchus the Serpent-Bearer and Serpens the Serpent. These two groups of moderately bright stars are connected and together occupy a giant hunk of sky. The brightest star in Ophiuchus is Ras Alhague, a second-magnitude sun. Serpens is split into two parts, Serpens Caput and Serpens Cauda, the brightest stars of which shine at magnitude 2.5. Serpens Caput means "head of the serpent," Serpens Cauda "the serpent's tail." This region begins to show many stars progressively nearer to the Milky Way, so scanning the area with binoculars is an enjoyable pastime.

Libra the Scales is a large group primarily composed of five bright stars, arranged roughly in a hexagon. The group's brightest star, Beta, named Zubeneschamali, shines at magnitude 2.6. Libra is another of the zodiacal constellations; the planets, Sun, and moon routinely pass in front of it. Nearby is the giant Scorpion called Scorpius, another zodiacal group, whose brightest star is Antares, a brilliant first-magnitude star rivaling Mars in deep orange color. The entire form of the constellation is studded with bright stars, making for a fine binocular scanning area. Many clusters and nebulae are littered around this area, including the bright groups of stars NGC-6231, M-6, M-7, and the globular cluster M-4, located near Antares.

South of the Scorpion lies Centaurus the Centaur, a large, cluttered assemblage of predominantly bright blue-white stars — an awesome sight to those of us who have an unobstructed southern horizon. Two of its treats are the giant galaxy NGC-5128, visible in binoculars as a circular haze, and the globular cluster Omega [ω] Centauri, the finest such object in the sky. It appears as a fuzzy naked-eye "star" or a large ball of milky light in binoculars. The dazzling suns Alpha [α] and Beta [β] Centauri are, unfortunately, too far south for most U.S. sky watchers.

There you have it. The spring sky offers many of the same treats as the winter sky, holding onto the last showing of the winter Milky Way and first light of the season for the summer Milky Way. In between lies the vast "hole in the sky" that looks outward to the great galaxies, a void so tremendous that its implications boggle the mind. Yet there are fine sights to see scattered across the spring sky, just waiting for patient eyes.

ASTRONOMY
Reviews

Super C-8 Telescope
Celestron International
List price: $1195.00

Recently Celestron came out with an improved version of its popular C-8 Schmidt-Cassegrain telescope (SCT) called the "Super C-8." The main difference between the Super C-8 and the standard model is the addition of a Byers worm gear clock-drive, one of the best drives available for any telescope.

While the Super C-8 has many advantages over the standard model, it also has its problems. The most objectionable that I have found is the tube's balance. The Super C-8 uses a standard C-8 tube and fork mount (albeit with a better drive) and an 8 x 50 viewfinder in place of the standard 6 x 30. While the new finderscope makes searching for faint objects a lot easier, it also causes problems because no attempt was made to compensate for the added weight of the larger viewfinder. Thus the telescope tends to "flop" suddenly when either the declination or right ascension axis is unlocked. This makes viewing difficult and possibly even dangerous — if the observer releases the declination lock while his head is still near the eyepiece, there is a good chance that as the telescope swings down to find its proper balance, it will hit the observer's head with enough force to give an unpleasant jolt. This is good for neither telescope nor observer.

The finderscope's aiming adjustment was also cumbersome. To change the aim, you must use a small screwdriver to adjust the three collimating screws. This calls for a flashlight and close attention as you tighten or loosen the screws. It's a bit of a three-ring circus to fiddle with the screws, watch what you are doing, and look through the scope to check how the alignment is going. I found it more practical to have two people adjust the aim of the finderscope — one adjusting the screws while the other looks through the finderscope. To overcome this, I think the adjustment screws should extend beyond the mounting bracket and have finger-knobs large enough to adjust with one hand while you look through the finderscope.

As far as optical quality goes, the Super C-8 continues the Celestron tradition. The telescope that I tested passed the "star test" (see ASTRONOMY, April 1983) with flying colors. The diffraction patterns were as close to perfect as I have ever seen.

The field tripod still leaves room for improvement. I found myself waiting an average of five seconds for the tremors to die down whenever I focused the scope or moved it. Another thing — I wish they'd built in a bubble level.

But overall, I found the Super C-8 to be a satisfactory telescope, with its major shortcomings in the tube balance and the design of the finderscope mount. Once these minor problems are overcome, the Super C-8 should join the ranks of the exceptional telescopes. *Scott A. Thurlow.*

Life in Space
The Editors of Time-Life Books
304 pages, hardcover, $39.95
Time-Life Books (1983)

Back in 1960, when *Life* magazine publisher Henry R. Luce called the original seven Mercury astronauts into his office to have their pictures taken, he must have been dreaming of the day when Time-Life Books could produce a comprehensive compilation of photographs like *Life in Space*. Interspersed with bits of text, this collection of photographs lasts for 304 pages. Its large format of 10¾" x 13¼" allows many full-page and two-page color photos, which constitute a picture history of the American space program to date.

The book details the story of space exploration from both human and technological viewpoints. It does this by showing spacecraft in action — either orbiting or blasting off the pad — and astronauts standing on aircraft carriers, floating in their capsules, or greeting their wives after safe landings. By showing this much in large pictures, a book like this one succeeds in communicating the story of Americans in space even without text.

Much of the entertaining material, such as descriptions of the tests Mercury astronauts were subjected to, shows up early in the book. After all, in 1960 the effects of space were unknown, so NASA poked, spun, twisted, dropped, squeezed, and tinkered with the seven astronauts in just about every conceivable way. All of this prompted the late Gus Grissom to react, "The organs of your body seem to be sloshing in all directions, and your head and feet feel full of blood. You now have only a short time before violent illness overcomes you."

But the Mercury seven — Scott Carpenter, Gordon Cooper, John Glenn, Gus Grissom, Wally Schirra, Alan Shepard, and Deke Slayton — overcame the odds with cool professionalism and a touch of "the right stuff." The book recalls an increasingly anxious yet composed Shepard as ground control problems delayed the first American space flight.

Canaveral: "We're experiencing problems."

Shepard: "Fix your damn problems and let's light this candle!"

Moments later Shepard began his 15-minute suborbital flight. In another section, the book relives John Glenn's precedent-setting ticker tape parade in New York City upon returning from his *Friendship 7* orbital flight, and we see an image that seems to summarize those first days of the space program — Glenn sitting beside John Kennedy, giving a "thumbs up" sign and a cheery smile as Kennedy looks on.

Other "firsts" in space are highlighted throughout the Gemini program and on through Apollo. Neil Armstrong's touchdown on the lunar surface in July 1969 is the third triumph of Americans in space, following the earlier Shepard and Glenn flights. The book proceeds into the 1970s, describing Skylab and the Apollo-

Soyuz mission, and gives detailed accounts and photographs of the Space Shuttles in action through STS-6, launched on April 6, 1983.

Some of the lighter moments in space come back to us, such as when rookie Gemini astronaut John Young — knowing full well that his commander Gus Grissom detested dehydrated food — pulled out a corned beef sandwich *en route* and offered it to Grissom. Or Grissom's naming his Gemini 3 spacecraft *Molly Brown* (as in "The Unsinkable . . .") after his Mercury capsule sank into the ocean, nearly drowning him, four years earlier. Or when Apollo 14 skipper Alan Shepard pulled two contraband golf balls out of his suit and teed off from the Moon's crumbly surface.

Tragedy also appears in this account of our exploration of space. In 1967 the first Apollo crew — Gus Grissom, Ed White, and Roger Chaffee — perished in a launch pad flash fire; we are reminded by a grisly photograph of the burned-out hull of the spacecraft. Twelve missions later, riding in Apollo 13, Jim Lovell, Jack Swigert, and Fred Haise survived an explosion in their craft's service module.

The book mentions the unmanned space probes — the Mariners, Pioneers, Vikings, and Voyagers — but it devotes only token space to them, including them as a kind of courtesy to JPL's deep space program.

The severest drawback to the book is its hefty price of $40. It is a lavish, colorful, stunning production — but in spite of its quality, many people won't want to pay the book's list price. If you are one of them, be sure to take the time to hunt it down in a library.

Life in Space is an unabashedly proud volume of America's story in space, its resulting triumphs in science and technology, ongoing spirit of exploration and adventure, and sense of patriotism. It is a marvelous collection of photographs from NASA and the pages of *Life* magazine, and is a must for the bookshelves of space buffs. *David J. Eicher.*

Relativity Visualized

Lewis C. Epstein
199 pages, softcover, $12.95
Insight Press (1983)

For many people, the two main problems with understanding the theory of relativity are that first, it seems contrary to experience (we never experience time dilation, for instance), and second, that it is difficult to visualize. The first problem dwindles as you become more familiar with the reasoning behind the concepts. But the second problem is less tractable and stems, I believe, from the way people think.

Recent research into the processes of mind suggest that the two halves of the brain govern different modes of thinking. Mathematicians and accountants, for example, are usually "left-brain dominant." They tend to think logically, analytically, and non-visually. Artists, writers, and many theoretical scientists are predominantly right-brain thinkers, stimulated by ideas that are visual, imaginative, dimensional, and not necessarily reasonable at first glance.

It is to right-brain thinkers that Lewis Epstein's *Relativity Visualized* should appeal most, although the book will be helpful to everyone who wants a simple overview of relativity.

The book explains relativity through *Gedankenexperimente* — "thought experiments" — so called by Einstein. These might also be called "what if" daydreams and are precisely the technique that Einstein himself used when he developed his ideas. Author Epstein augments written descriptions with many easily understood cartoons and simple diagrams.

Cartoons may not seem like the most appropriate way to present one of the most influential scientific theories of all time, but any method that leads the reader to a correct and better understanding of the concepts is not to be scoffed at. Later, if the reader wishes to explore relativity with full mathematical rigor, he can look up one of the many texts available. But this book is a good place to start for simple understanding of the topic.

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Relativity Visualized deals with both special and general relativity, including the speed of light, time dilation, space contraction, curved and warped space, the origin of gravity, black holes, and other ideas with direct bearing on cosmology and space travel. That's a lot to cover in less than 200 pages, but the author does it by highlighting the basics without getting bogged down in details unessential to understanding the concepts.

The book contains a number of short questions and answers designed to expand and reinforce comprehension of the topic. Each chapter concludes with short essays having titles such as "Inside a Physicist's Head," "How to Draw Infinity," and "The IRS."

To the author, the ultimate description of a physical law or cosmic reality is not a mathematical formula — although I'm sure that Epstein would agree that formulas are necessary for full development of a theory. Rather, he prefers a non-mathematical and visualizable concept that can be readily grasped and understood.

He calls his non-mathematical version a "myth" that serves to enable the "inquiring mind to feel at home in a mysterious universe." The myth must also "save the phenomena" — it must explain accurately what is observed in nature. For example, the Hindu cosmological myth that the Earth is supported underneath by gigantic turtles is bad, not because it seems silly, but because we don't find any turtles down there. The relativity myth Epstein presents is good because it is simple and because it explains what has been observed so far in nature.

Relativity Visualized certainly isn't the first book to attempt a simple, non-mathematical treatment of the subject, but it is the best I've seen. (Other good explanations can be found in *Physics for Poets* by Robert March and *Relativity and Cosmology* by William Kaufmann.) Epstein's book is not a rigorous treatment, but it is highly readable and easily understood. It'll prove enjoyable to everyone from bright grade school children up to college professors in need of a quick review. *Larry Sessions.*

Catalogue of Radial Velocities of Galaxies

G.G.C. Palumbo, G. Tanzella-Nitti, and G. Vettolani
575 pages, hardbound, $94
Gordon and Breach (1983)

This work, compiled by three Italian astronomers, contains radial velocity figures for some 8,250 galaxies. For each object, it provides right ascension and declination for the epoch 1950.0, galaxy names (many galaxies have multiple catalog numbers), types of velocity observations, heliocentric radial velocities, galactic correction for the Sun's motion, and comments.

The Cambridge Deep-Sky Album

Jack Newton and Philip Teece
126 pages, hardcover, $19.95
Cambridge University Press (1983)

The Cambridge Deep-Sky Album is a picture book of the Messier objects and a handful of additional NGC galaxies, clusters, and nebulae. In addition to similarly scaled photographic reproductions, it provides data and a short description of the physical nature of the objects. The authors also give short references to telescopic appearances of the pictured deep-sky objects.

Activity in Red-Dwarf Stars

P.B. Byrne and M. Rodono, eds.
669 pages, hardcover, $85
D. Reidel (1983)

Astrophysical problems that used to be considered exclusively solar have now become central topics in stellar physics. The large-scale phenomena observed on stars (spots, flares, plages, coronae) can be seen in much greater detail on the Sun — which makes stellar microphysics available to astronomers. This volume of scientific papers contains the proceedings of an IAU colloquium held in 1983.

The Physics of Stars

S.A. Kaplan
Translated by Renata Feldman
158 pages, hardcover, $34.95
John Wiley and Sons (1982)

A Soviet astronomer explains the basic physics of stellar interiors. The author gives the best description: "You will find here neither a description of the beauties of the constellations nor a comparison of stellar dimensions with earthly objects. To us, stars, although beautiful, are objects of physical study."

A handful of equations is used, and Kaplan assumes an acquaintance with freshman college physics. The book was originally published in the USSR as *Fizika Zvezd*, third edition, in 1978.

Spacewarps

John Gribbin
211 pages, hardcover, $16.95
Delacorte Press/Eleanor Friede (1983)

Physicist John Gribbin investigates the phenomena of black holes, quasars, the Sun, neutrinos, and life in the universe. He explores the possibility that Einstein's ideas do not constitute "the last word" in physics and looks at the dilemma of creating a Unified Field Theory. He also surveys the relationship between space and time, asks "Is our place in the universe special?" and ponders other ideas, such as the existence of a supermassive black hole at the Milky Way's center.

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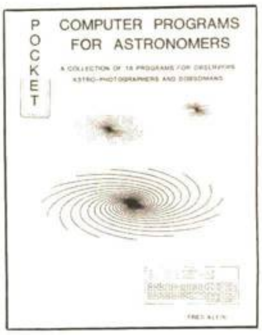

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Eye on the Sky

Venus Shines at Sunrise

by
Fred Schaaf

In the Mojave Desert, stars in the extreme southern Milky Way, including parts of Puppis and Vela, show up with a 5-minute exposure on 400-speed film. Photo by Richard Berry.

Venus and a crescent Moon glow in the predawn twilight that silhouettes the Paris skyline. Olivier de Goursac caught the pair with 400-speed film and a 10-second exposure.

The Wanderers

Over the last two months, there were weeks when we could see all the planets at once — in fact, Earth's eight fellow worlds were confined within 60° along the ecliptic for a few mornings, the most concentrated display of all the planets to occur during this century. The next two months offer many more modest events, and all the outer planets are brightening toward their spring or early summer oppositions.

The most noteworthy planet during all of spring is **Mars**. The apparent motion of Mars against the stars slows greatly this month, but its rapid brightening still accelerates. Earth is quickly catching up to Mars in a race around their orbits, and therefore the Red Planet increases in brightness by almost a full magnitude during March. The predictions from the U.S. Naval Observatory show the planet brightening from magnitude +0.5 to −0.4 in March, but perhaps we should expect the range to be from about +0.3 to −0.6 (possibly even a bit brighter).

Thus deep orange Mars should rival the light orange star Arcturus by about the 10th. Remember, however, that when Mars rises in the late evening this month, Arcturus will already be rather high in the southeast and therefore less dimmed by atmospheric absorption. By the end of the month, though, Mars is spectacular, regardless of how low you see it. You will have no trouble finding the ruddy beacon as it slows almost to a halt in eastern Libra, approaching to within just a few degrees of dim Theta (θ) Librae.

The planet **Saturn** rises early in the evening. Like Mars, this world is on its way to an early May opposition. Saturn brightens only slightly, to about magnitude +0.4 by the last day of March. It is now moving at nearly its slowest possible speed as it moves westward against the starry background. This retrograde motion brings Saturn just slightly closer to the wide double star Alpha (α) Librae.

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.

Rising much later than Mars, on the other hand, is the still brighter planet **Jupiter**. After midnight, Jupiter appears with Sagittarius, the constellation it joins for an early summer opposition. Brightening from −1.6 to −1.8 magnitude, Jupiter drifts only about a degree north of the bright globular cluster M-22 (near the Teapot's top) and, slowing, draws close to the interesting pair of stars Nu^1 (ν^1) and Nu^2 (ν^2) Sagittarii. Jupiter will undergo some superb close conjunctions with these stars this year.

Uranus is in a sparsely starred region northeast of Antares, where it begins retrograde motion on March 18. It may require binoculars even in very dark skies, as will Neptune.

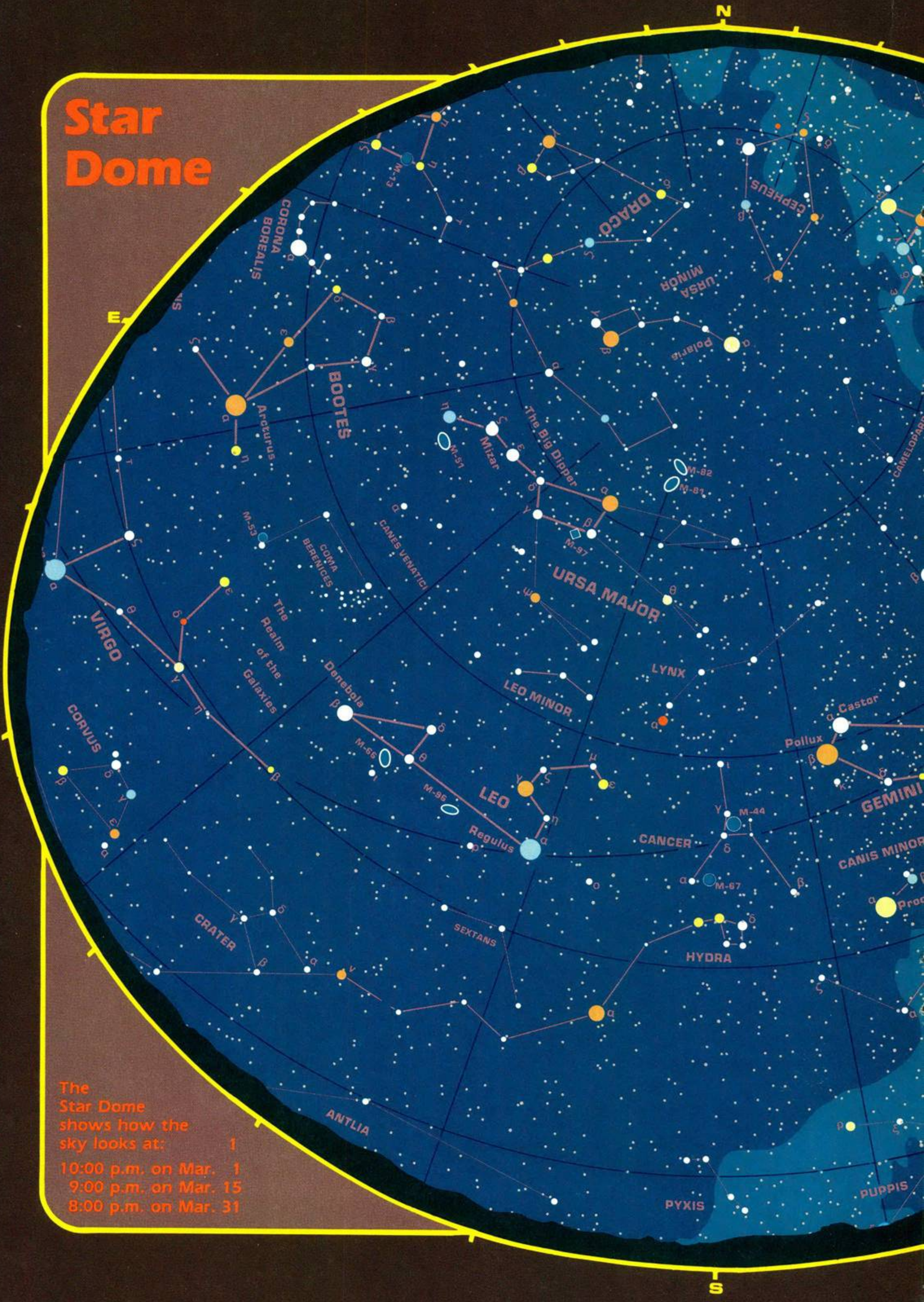
Neptune remains in that wonderful nebular region, Sagittarius. The distant planet has its heliocentric conjunction with Jupiter on the 16th. As viewed from Earth, Jupiter and Neptune will be separated by many degrees. But as viewed from the Sun, Jupiter will appear to pass Neptune as it draws even with Neptune in their race around the Sun. An observer in the jovian system would now see Neptune at opposition (a bit brighter than as seen from Earth) for the first time in 13 years.

Venus is the planet for people who rise in morning twilight this month. Its elongation changes from 27° to 20° during March. Although Venus now shines with only a magnitude −3.3 brilliance, that is still far more impressive than Jupiter and Mars, which are both better placed for observing. While Jupiter and Mars shine in the southwest and southeast before dawn, Venus ascends in Aquarius. Venus reaches the aphelion point of its nearly circular orbit on the 24th.

Although Mars is the most prominent planet this month, **Mercury** pulls away from a March 8th superior conjunction with the Sun to emerge into prominence late in the month. Mercury, which reaches perihelion the same day (the 24th) as Venus reaches aphelion, should be easily visible in the west in the middle of evening twilight. The speedy planet will reach greatest elongation in this spring apparition on the night of April 2.

None of the truly superb meteor showers occur in March, but two major (yet unfortunately faint) asteroids lie in

Star Dome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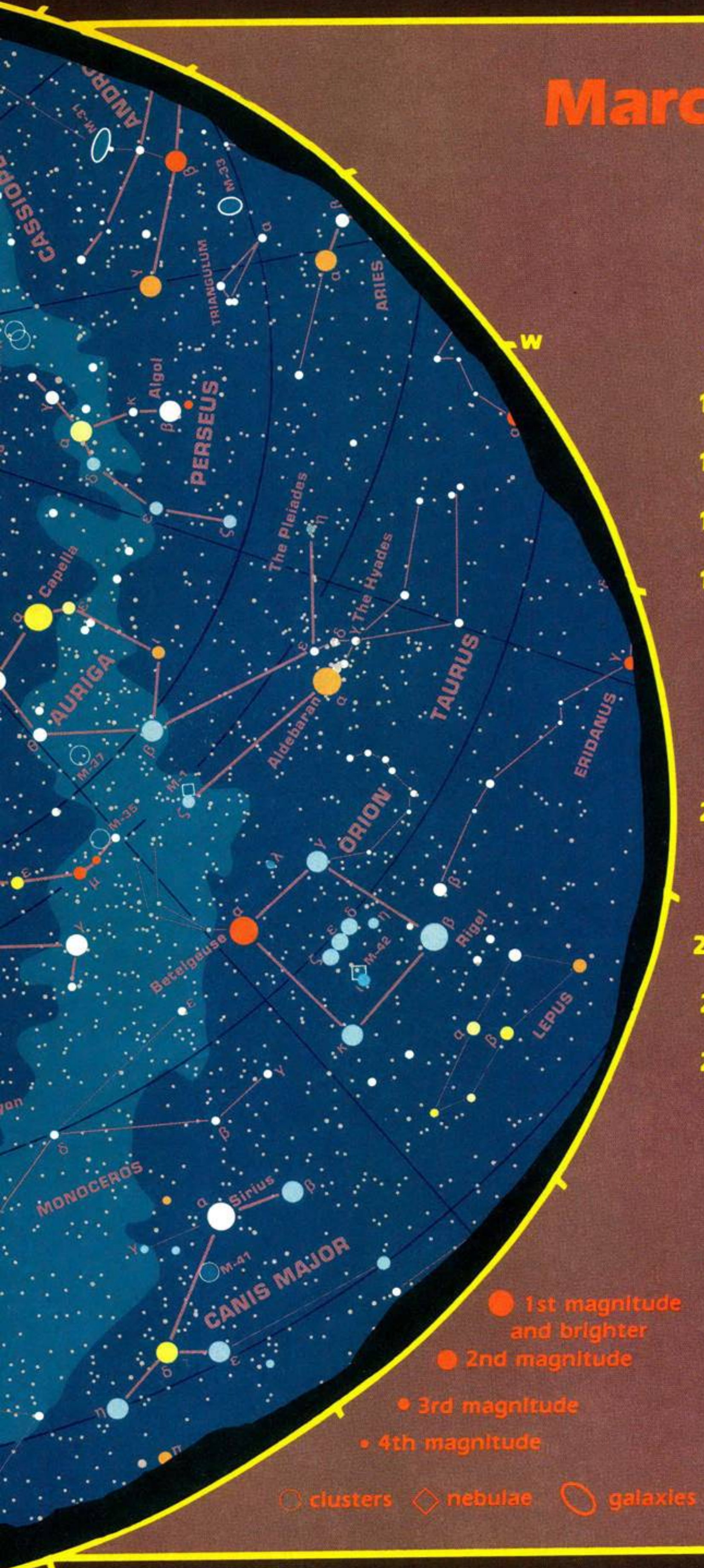
M-81
M-97
M-53
COMA BERENICES
CANES VENATICI
URSA MAJOR
CAMELOPARD
VIRGO
The Realm of the Galaxies
Denebola
LEO MINOR
LYNX
Castor
Pollux
GEMINI
M-65
M-66
M-95
LEO
Regulus
CANCER
M-44
M-67
CANIS MINOR
Proc
CORVUS
CRATER
SEXTANS
HYDRA
ANTLIA
PYXIS
PUPPIS

The Star Dome shows how the sky looks at: 1

10:00 p.m. on Mar. 1
9:00 p.m. on Mar. 15
8:00 p.m. on Mar. 31


CASSIOPEIA
ANDRO
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The Pleiades
The Hyades
Capella
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Aldebaran
TAURUS
ERIDANUS
M-37
M-1
M-35
ORION
Betelgeuse
Rigel
M-42
LEPUS
MONOCEROS
Sirius
M-41
CANIS MAJOR
1st magnitude and brighter
2nd magnitude
3rd magnitude
4th magnitude
clusters
nebulae
galaxies

March Sky Almanac

2nd The Moon is at apogee at 5:54 a.m. EST: 252,719 miles. Also, New Moon is at 1:31 p.m. EST.

8th Mercury is in superior conjunction

10th First Quarter Moon is at 1:27 p.m. EST.

16th The Moon is at perigee at 4:12 p.m. EST: 221,923 miles.

17th Full Moon occurs at 5:10 a.m. EST.

18th By about now, you ought to be able to catch sight of Mercury very low in the west after sunset. Between now and mid-April will be the best apparition of the year for the planet. Also, Uranus is stationary in right ascension.

20th The vernal equinox occurs when the Sun crosses the celestial equator northbound at 5:24 a.m. EST; spring begins for Earth's northern hemisphere.

22nd Asteroid Ceres is in conjunction with the Sun.

24th Last Quarter Moon happens at 2:58 a.m. EST.

29th The Moon is at apogee at 11:07 a.m. EST: 252,491 miles.

Moonlit plumes of steam from Old Faithful geyser greet the rising stars of Orion. For this photo, Dewey Vanderhoff set his camera at f/2.8 and used a one-minute exposure on 400-speed film.

interesting regions of the heavens this month. Dim **Juno** is about 5° south of Aldebaran at the end of March, and **Vesta** (visible in good binoculars) is passing between the horns of Taurus the Bull (see The Backyard Astronomer for their positions). Vesta takes part in some fascinating conjunctions this year, perhaps the best of which is its passages next month past the Crab Nebula supernova remnant (M-1) in Taurus, and later right through the fine star cluster M-35.

Our final planet of note this month is our own **Earth**, which reaches the vernal equinox point in its orbit. For the northern hemisphere of Earth, spring begins 10:25 UT on March 20. As seen from Earth, this is when the northward-moving Sun appears to cross the celestial equator.

The Starry Sky

Let us continue our theme of the last few months by examining patterns of stars, both apparent and real. Constellations and asterisms fall into the first category; clusters and associations of stars make up the second. March evenings make for a good time to see outstanding examples of both types of pattern.

Asterisms are star patterns other than those that make up the traditional constellations. And like the constellations, their stars are not normally physically associated. We've previously looked at two, the Winter Triangle and the Egyptian X. Better known than these, however, are the vast asterisms in the same area — the **Winter Hexagon** and the **Heavenly G**. The Winter Hexagon is formed by lines connecting the stars Aldebaran, Capella, Castor, Pollux, Procyon, Sirius, and Rigel, with Betelgeuse at the center. The Heavenly G uses the same stars, but the last line must be drawn from Rigel to Betelgeuse instead of Rigel to Aldebaran — it forms the horizontal line in the G.

A list of the component stars of these asterisms reads like a stellar *Who's Who* of winter. All but one of the stars are first magnitude or brighter, so these forms stand out well even in light-polluted skies or on evenings bright with moonlight. **Aldebaran** is the eye of **Taurus** the Bull, and **Capella** is the leading luminary of **Auriga** the Charioteer. **Pollux** and **Castor** mark the heads of the twin brothers of **Gemini**. **Procyon** and **Sirius** are the Dog Stars, belonging to **Canis Major** and **Canis Minor**, respectively. And of course **Rigel** and **Betelgeuse** are the brightest stars of **Orion**, who now tilts into the west.

The two Dog Stars and the stellar pair marking the Twins are still well placed in March — they also serve as good examples of stars that just happen to lie at similar distances. Sirius and Procyon are about 9 and 11 light-years away, respectively, so Sirius really is a brighter star than Procyon. In the case of Pollux and Castor, the light from the two star systems is about equal, but Castor appears somewhat fainter because of its slightly greater distance. Procyon, by the way, is the only prominent star in the little line that forms Canis Minor, the Little Dog. It has been said that the constellation Canis Minor looks more like a tail without a dog!

Appearances may be deceiving, as shown by the fact that Aldebaran is not a member of the **Hyades** star cluster in Taurus (the cluster is actually about twice as far from us as that red giant star). Most clusters, however, really are what they seem — a grouping of stars in space, all at roughly the same distance from us. It is interesting that all five of the closest star clusters can easily be seen in the sky at once.

Two of these clusters are departing in March: the **Pleiades** and Hyades in Taurus. One is now overhead: **M-44**, the Beehive cluster in **Cancer** the Crab. Cancer would be perhaps the least interesting constellation of the Zodiac *were it not for this cluster*. Unlike the Pleiades and Hyades, M-44 is a bit too distant for its stars to appear as separate points of light to an unaided eye. A few of its members are bright enough to glimpse without optical aid in dark skies, but their neighbors are close by and distracting. What a fine distraction it is, however, to see the Beehive as an unevenly shimmering patch of light. You may recall when Comet IRAS-Araki-Alcock passed by M-44 last May, like a bigger, brighter Beehive. Just like a bright comet, the Beehive deserves to be observed with binoculars.

South of M-44 and the dim stars of Cancer is the rather prominent head of **Hydra** the Sea-serpent. Following Cancer (which itself follows Gemini) is the much more prominent **Leo** the Lion, with the bright star Regulus. But our other close clusters lie north and east of rising Leo. One is the star cluster in Coma Berenices, **Mel 111**, a bright naked-eye scattering. The other may be a real surprise to many amateur astronomers.

Our final cluster contains many of the bright stars visible in March skies — the **Ursa Major star cluster**, the closest of all. At 75 light-years away, it is a little more than half the distance of the Hyades. But if the Hyades are spread over a field about 7° wide (if we count only its most prominent members), how could we overlook a much closer (and presumably larger-looking) cluster? The Ursa Major cluster is *too* widely spread out, although its brightest members are indeed often identified together — the five stars composing the Big Dipper!

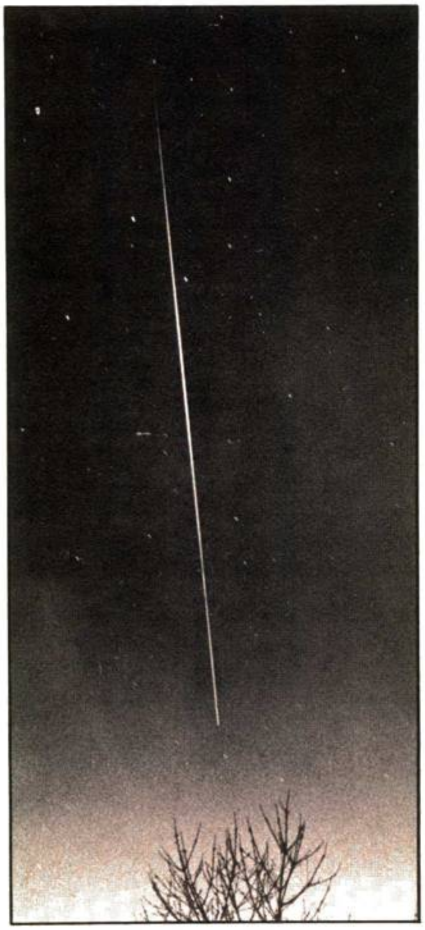
The **Big Dipper**, an asterism that forms part of the large constellation Ursa Major, starts to roll high in the northeast on March evenings. All but handle-end Alkaid and bowl-end Dubhe are members of the Ursa Major cluster. Most of the Big Dipper's stars are related to one another. From farther away, the Ursa Major cluster would begin to resemble the Pleiades, although these suns are far less luminous than the Pleiads.

One further fact about the Ursa Major cluster makes it a captivating subject for March observation and thought. There are other stars in our sky, many dozens of light-years from the cluster, which seem to travel in the same direction and with the same speed as the cluster members. Have these other stars drifted away from the original tighter bunching of the cluster? Perhaps. These stars make up the **Ursa Major stream** and are found from Ophiuchus to Auriga — in other words, this stellar caravan, hundreds of light-years across, is all around us. And what stars belong to this stream? The bright stars in Corona Borealis, Eridanus, and the brightest star of them all — Sirius — seem to be members.

Skylore

In last month's discussion of Monoceros and unicorn-lore, we examined the origin of Biblical use of the word "unicorn" and discovered it was a product of mistranslation by Septuagint scholars. The Hebrew original is *re'em*, a word best translated as "wild ox." Why did the scholars identify this creature with the legendary unicorn?

In the January Skylore, I mentioned the idea that the unicorn itself was derived from a misunderstanding of Mesopotamian bas-reliefs that portrayed the ox (perhaps Taurus the Bull) in profile and therefore showing just one horn. This hypothesis was first advanced around 1892.



During its last mission, many people saw the Space Shuttle *Columbia* as a moving "star" at least as bright as Venus. H.J. Arnold used 400-speed film for this unguided shot.

I have also noted that the lion facing the bull on these bas-reliefs might be Leo facing Taurus, and might provide an explanation for the connection of the unicorn and lion in legend and on emblems like the British royal coat of arms. Isaac Asimov points out in his *Guide to the Bible*, however, that this coat of arms was formed in 1603 when Scotland and England combined under one rule; it merely resulted from the combination of the unicorns of the Scottish emblem with the lions of the English one.

Nevertheless, several decades before 1603, the English poet Edmund Spenser mentioned a legendary battle of the unicorn and lion in his allegorical epic poem *The Faerie Queene*. Also, the *Oxford English Dictionary* quotes a statement connecting the two creatures that dates from around 1300. Did the enmity of Scotland and England produce an allegory about the animals' battle, or did Scotland adopt the unicorn as its symbol to oppose England's because of an already existent legend of lion and unicorn as enemies?

The Middle Ages saw the creation of a famous legend that the unicorn could only be captured by a virgin, who alone could coax the fierce creature to mildness. There is also an old tradition that the unicorn, if pursued, could leap off a high cliff and land safely on its horn! A very ancient piece of lore attributes to its horn the power of rendering poison harmless if the horn is used as the drinker's cup. Unscrupulous sailors who knew of this belief sold to the gullible the horn of the narwhal, an aquatic mammal whose one spiraled, forward-pointing tooth can be as long as 20 feet — once again a fact that seems stranger than fiction! The modern image of the unicorn usually has this spiraled horn and also the beard of a goat.

The poison-defeating virtues of the unicorn remind us that the only real one-horned land creature has been hunted for the legendary aphrodisiac properties of its horn. I am referring to the rhinoceros, whose "horn" is actually a fleshy concretion of hair. Some people suggest that the rhino may have been the source of the Greek unicorn. I am skeptical for many reasons, though Pliny's comment that the unicorn had the feet of an elephant might seem suggestive. (Strictly speaking, by the way, the rhino's feet are very different from the elephant's.)

Not surprisingly, a unicorn is not the only animal to occupy the position of the constellation Monoceros. The Chinese placed asterisms here representing canals and a kitchen. The Chinese, however, did have their own legends of an animal with one horn in its forehead.

The Chinese "unicorn," usually called the *k'i-lin*, was very gentle and was one of the four beasts of good omen. (Another was the Chinese dragon, who was also very different from the Western counterpart that is given the same name.) For interesting stories about Chinese unicorns and their encounters with Confucious and Genghis Khan, see *The Book of Imaginary Beings* by Jorge Luis Borges.

Despite cheapening by modern commercials, and renderings on everything from ashtrays to lampshades, the unicorn retains his age-old power in our imaginations. It is fitting that his constellation, though faint, is rather mysterious. This creature expresses the wonder at the heart of fantasy. Wonder that overwhelms us compels us to say, in words from Shakespeare's *Tempest*, "Now I will believe that there are unicorns."

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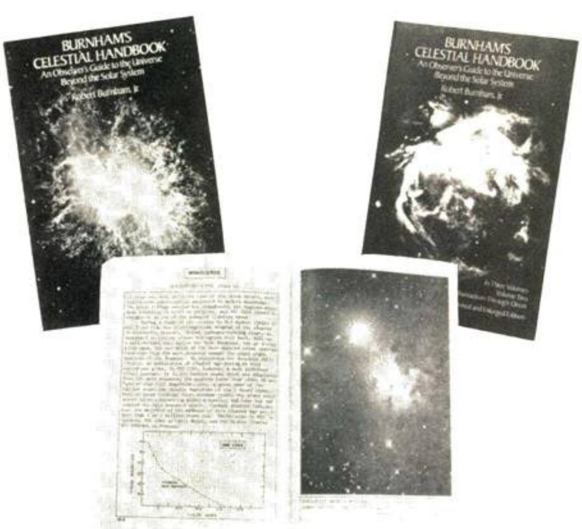
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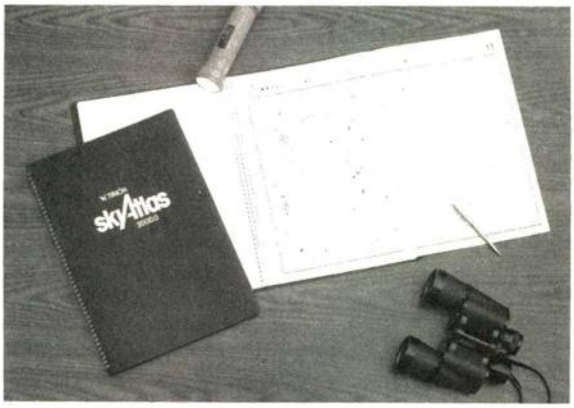

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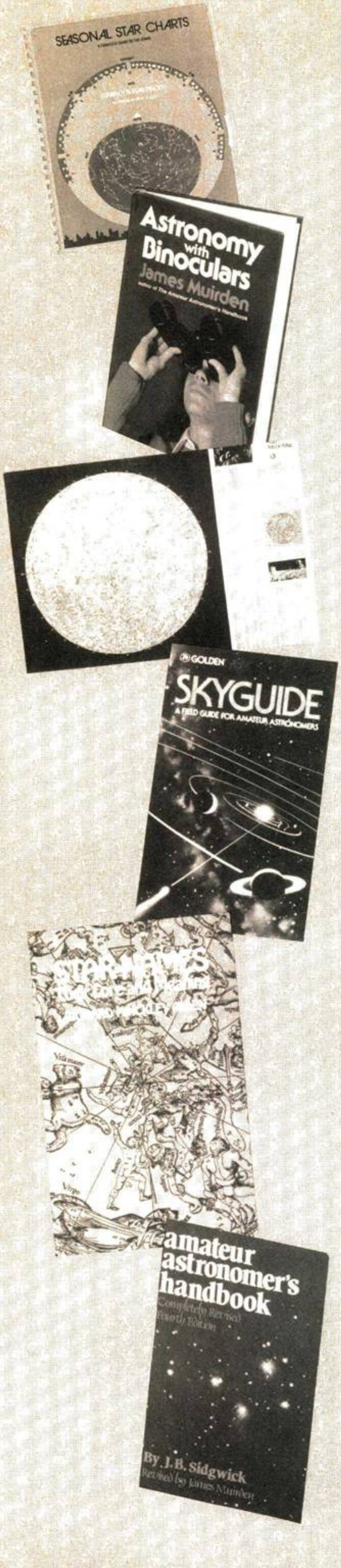
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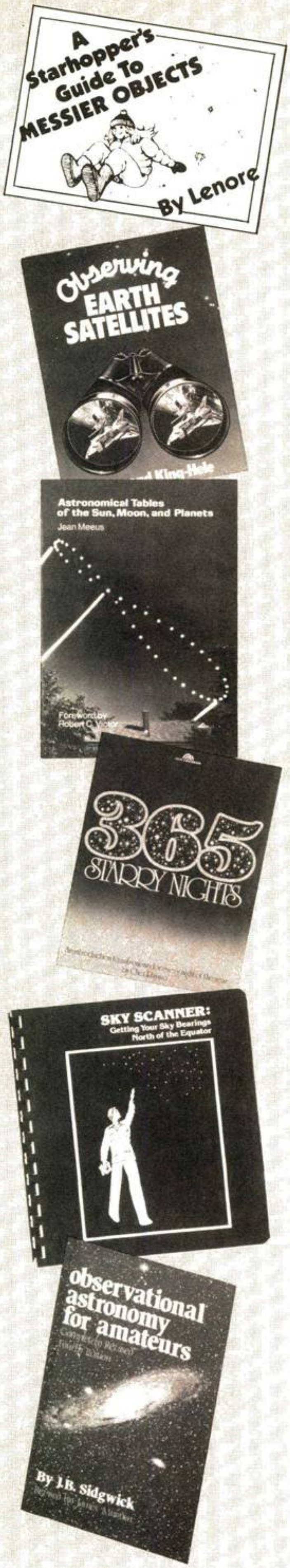
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Be a Copy-Cat!

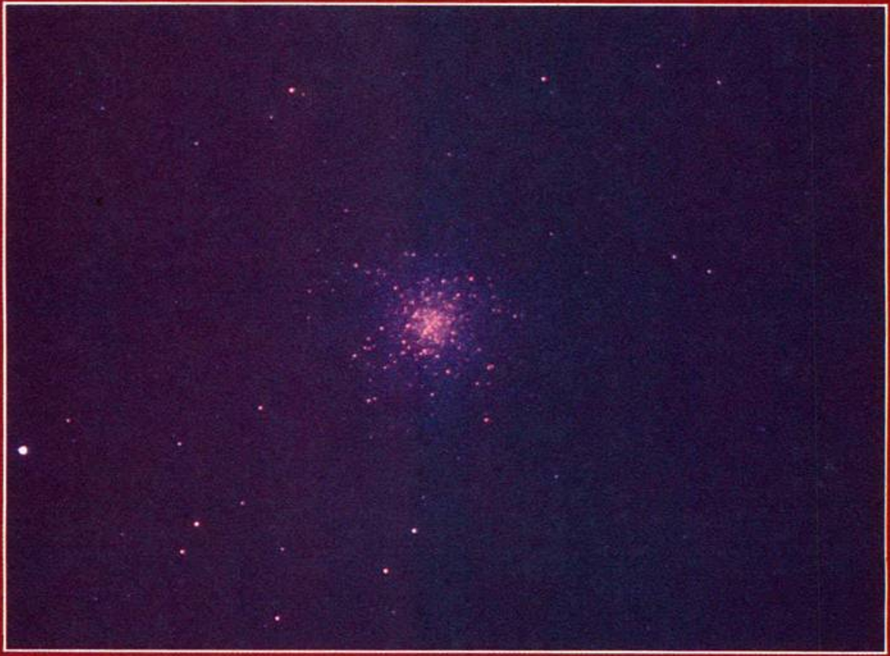
Photography in Astronomy

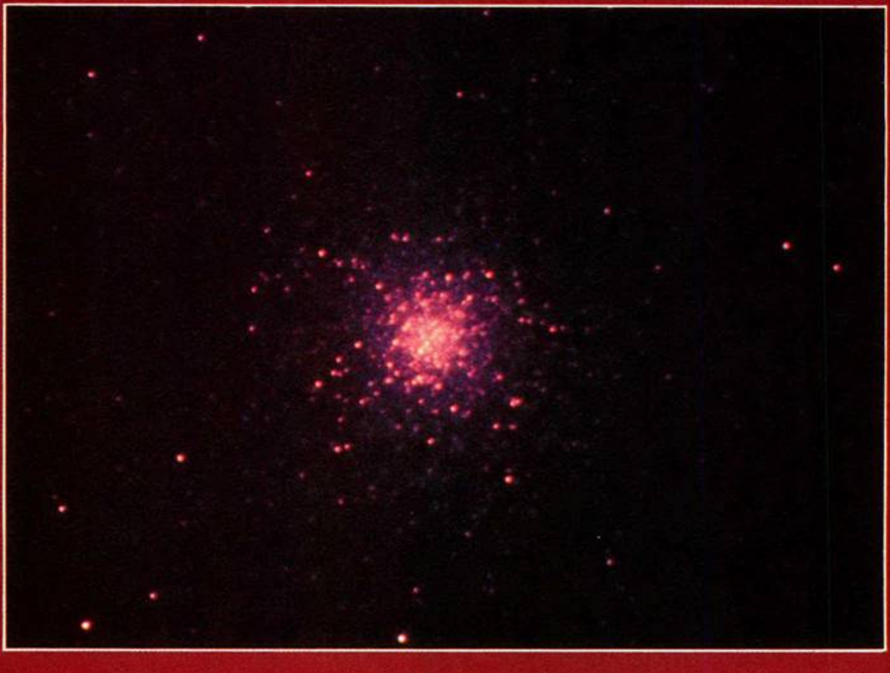
by
Clive Gibbons

You've just returned from the photofinisher, where you've picked up your latest astro-slides. You examine them closely. Yup, there's M-42 and there's the Double Cluster. They're all well focused and the guiding was good, but they seem to lack something. Nice shots, but they just don't have any zip — no pizzazz.

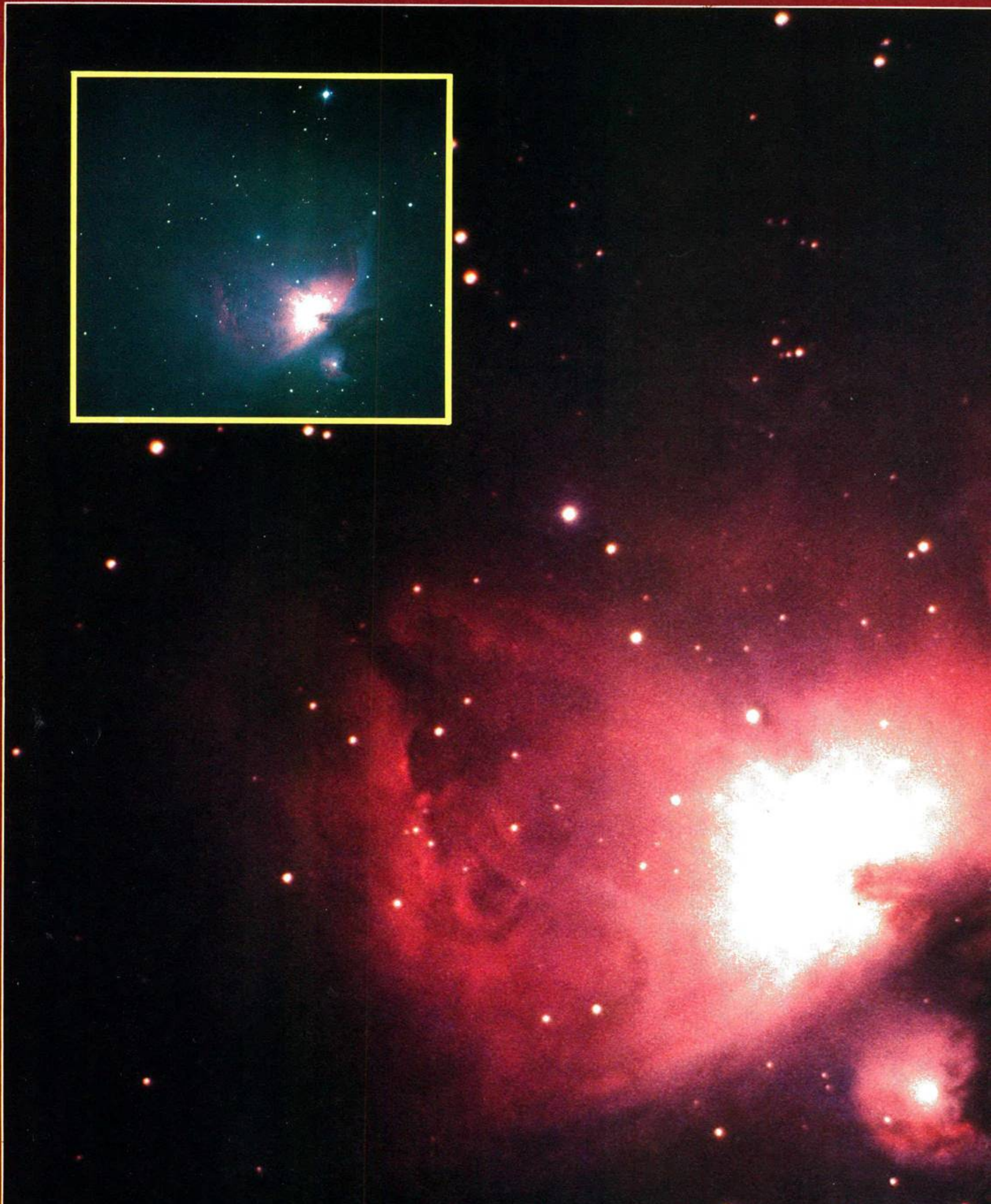
Sound familiar? It's a common complaint, and chances are, you aren't doing anything wrong. It's just that most deep-sky objects are low-contrast phenomena — they don't stand out boldly against the night sky. As if this weren't enough, both film hypering and light pollution have contrast-lowering effects. The result: Most of your deep-sky shots look washed out. So the secret of snappy astrophotos is to *increase* contrast — and the easiest way to do this is to copy your slides.

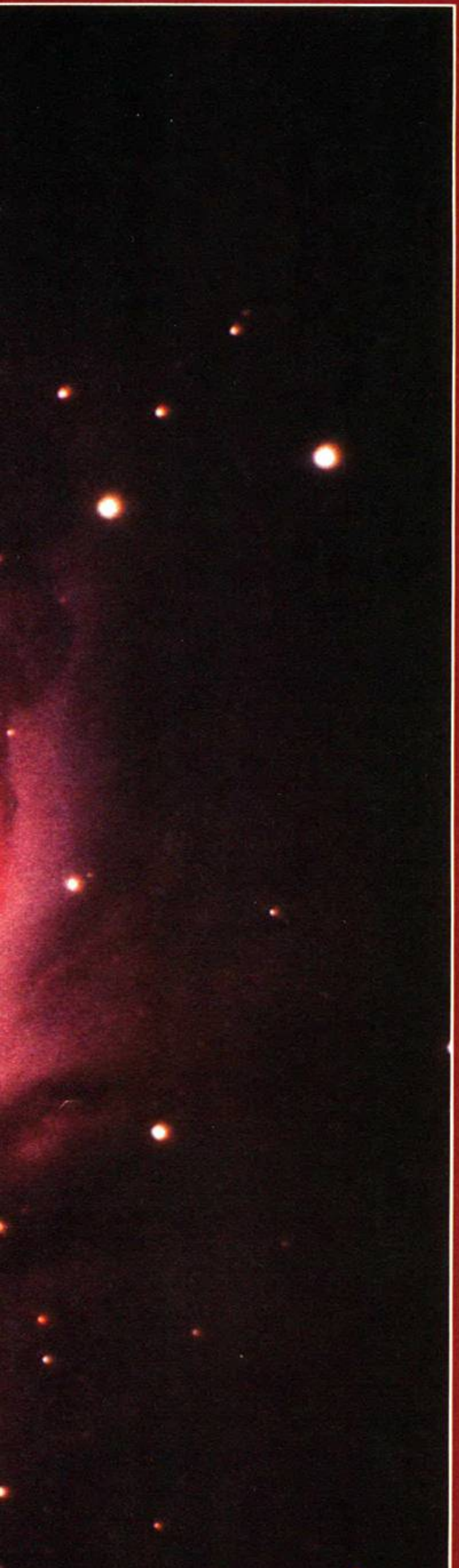
The simplest way to copy your slides is to send them off to a photofinisher. It saves you from having to buy new equipment, and it's relatively cheap. This method will cost you more in the long run, however, and besides, you'll have little or no control over the end product. For an investment of about $100 for a zoom slide copier and some ordinary off-the-shelf slide film, you can learn to copy slides yourself. Any nebulosity recorded on your original slides can be greatly enhanced. Star clusters can take on a whole new look as the faint, nearly





Light pollution and fog from gas hypering mar the original shot (top) of the globular cluster M-13 in Hercules, taken with hypered 400-speed film and a 30-minute exposure at f/10. By slightly underexposing the copy, the cluster stands out far better — and it has also been enlarged two times. Photos by the author.





The original photograph (inset) of M-42, the Orion Nebula, was a 45-minute exposure at f/8 taken on 400 speed film. Light pollution fogged the slide, turning the sky an ugly green. By copying onto 100-speed film using a CC30M color correction filter, the green background was eliminated, and the Great Nebula enhanced. Photos by the author.

invisible stars on your original shot leap into view on the copy.

The basic system uses your 35mm SLR camera, a slide copier, and a bright source of illumination. Two types of slide copier are readily available in most camera stores: the tubular "zoom" type, which employs a variable power lens system, and the "bellows" type, which uses a focusing bellows and a macro lens. While either is satisfactory for copying astronomical slides, the zoom type is usually cheaper, since it uses a slower, simpler optical system — one that may require quite a bright source of illumination. A slide projector, a movie light, or even the Sun can supply the necessary photons. You may be tempted to use a standard light bulb, but be warned — they're usually too faint and/or too yellow to give good results. Also beware of high-wattage movie lights. They may put out a lot of light, but at close range they can melt your slides.

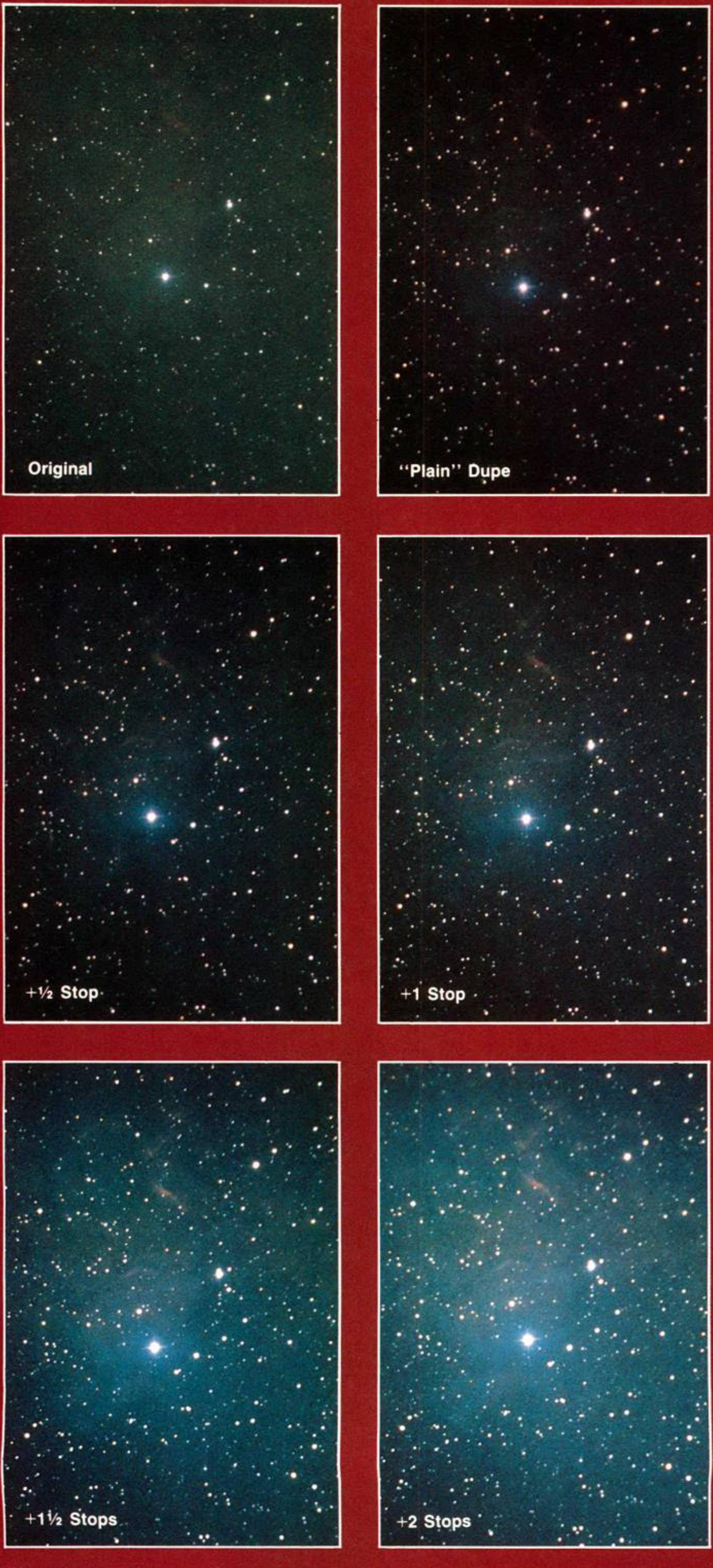
To get a pleasing color balance on copy slides, it's important to have the right combination of light source "color temperature" and film type. That is, if you're going to use a tungsten light source (like a movie lamp), you should use a film that's color balanced for tungsten light. Remember those party shots you took last Christmas without your flash? And how everyone in the pictures seemed to have a bad case of jaundice? You'll get the same effect using daylight-balanced slide film with a tungsten light source. The trick is to use a #80A filter to "blue-shift" the light so that it approximates the color of daylight. (It's much simpler just to use tungsten-balanced film.) While slide projectors usually have tungsten bulbs (some don't), a few even have built-in blue filters. You'll need to do a little experimenting to determine what gives the best results. If you use the Sun or an electronic flash, daylight film without filters should achieve good results.

It's important to determine the correct exposure before you make any copies. It seems straightforward enough: Just pop your slide into the copier, do what your camera's light meter says, and presto — you'll have a grossly overexposed copy. The problem is with the camera's meter. It assumes that your original slide is transmitting 18 percent of the light hitting it. But your slide is probably much darker than this. Your camera's meter will give an exposure value that will produce a copy slide having 18 percent light transmission — much too light. To avoid this, calibrate the exposure by using a slide of an average daylit scene. It's also a good idea to bracket your exposures, that is, take a picture at the shutter speed indicated by the light meter, then take another at an f-stop faster, and a third at an f-stop slower. This not only ensures that at least one of the copies will turn out, but each exposure will enhance different parts of the original subject. If the original slide is sky-fogged, a slightly underexposed copy can darken the sky while retaining most of the stars and nebulosity. A slide of a star cluster with a dark background can be overexposed in the copy version to enhance the stars while still retaining a dark background. The copy won't actually *contain* more stars than the original, but those present won't go unnoticed.

Slide copying has another quite obvious purpose. It protects your precious originals from the rigors of constant handling. It also lets you send your work to ASTRONOMY magazine without having to worry about what you'll have to show to your friends.

But for all these glowing attributes, copying must have its drawbacks, right? For everything gained, something must be lost, and in this case, it's image sharpness. You may not notice any loss in the first-generation copy, but try making a copy of a copy of a copy and you'll get the point. Also, if you enlarge the original slide to center an object better or to make it appear larger in the copy, the sizes of the star images will grow proportionately.

There's one other thing you might notice in your copies that isn't as apparent in the original sides: grain.



Jack Newton's original shot of IC-405, a faint nebulosity in Auriga, was a 15-minute exposure at f/5. The photo reveals some of the object's subtle structure, but copies of the slide made with additional exposure improve the range of densities, as this series illustrates.

And the more you enlarge the originals, the grainier the copies will appear. It's very difficult to eliminate this increase in graininess, but you can keep the problem down by not push-processing the originals and by minimizing copier magnification. You'll find that certain objects have enough contrast to start with, such as bright aurorae or the Moon. Some nebulae, like M-42, contain such a wide range of brightness that copying with ordinary slide film will completely burn out detail in the brightest regions. To maintain contrast at a desirable level in these cases, a special slide copy film is available from Kodak. Called 5071 Slide Duplicating Film, it comes in 36-exposure rolls and it's compatible with E-6 processing, which means that your local photofinisher can process it for you. You'll also find that it is very slow (ASA 4!) and needs color correction filters to achieve perfect color balance. But you can get quite acceptable results by using a tungsten light source without filters.

A final word on film: Try to avoid using the same type of film for the copies that you used for the original pictures — don't use Fujichrome 100 to make copies of Fujichrome 100 originals, for example. This will only enhance the specific film's color bias. If the original is a little magenta, then the copy will be a lot magenta. Using Kodachrome 64 to copy Fujichrome 400 and Fujichrome 100 to copy Ektachrome 400 generally gives pleasing results.

By being consistent in your method, keeping careful records, and learning from your mistakes, it's possible to get successful copies over 90 percent of the time. And once your first successful slide copies come back, you'll wonder how you lived without them. But watch out — copying can be highly addictive. You may find yourself spending more time making copies than taking originals!

Editor's Note: While ASTRONOMY appreciates original slides, good "dupes" reproduce well and save wear and tear on your originals.

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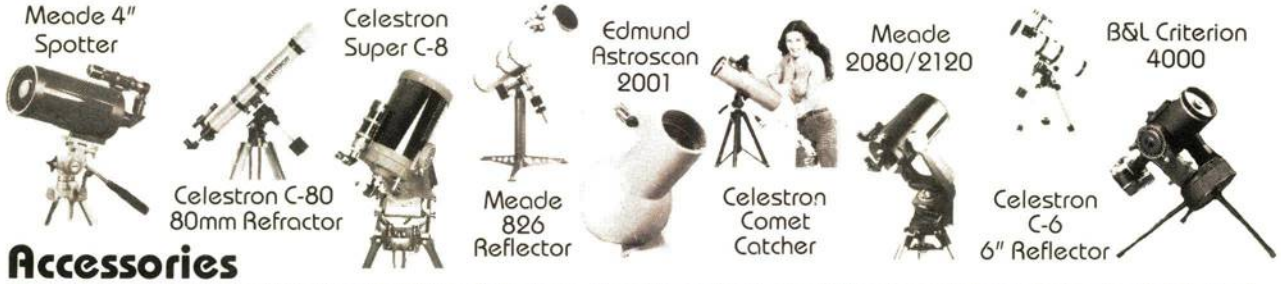

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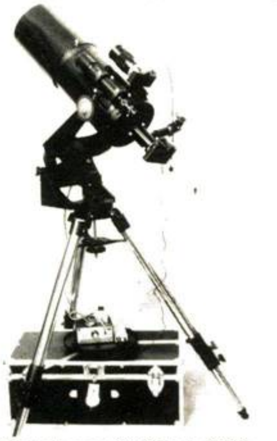

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ASTRO NEWS

Fourth Orbiter Joins Fleet

NASA's Space Transportation System flotilla is nearly complete with the recent addition of the orbiter *Discovery*.

With parts of the fifth and final orbiter, *Atlantis*, lying nearby, *Discovery* was backed out of a hangar at the Rockwell International plant in Palmdale, California, and towed to nearby Edwards Air Force Base, where it was mated to its Boeing 747 carrier plane.

Before crossing the country to Cape Canaveral, *Discovery* made a brief stop at Vandenberg Air Force Base on the California coast. In late 1985 Vandenberg will become the second Space Shuttle launch site, used for missions requiring polar orbits. *Discovery* is the orbiter scheduled for the first Vandenberg launch.

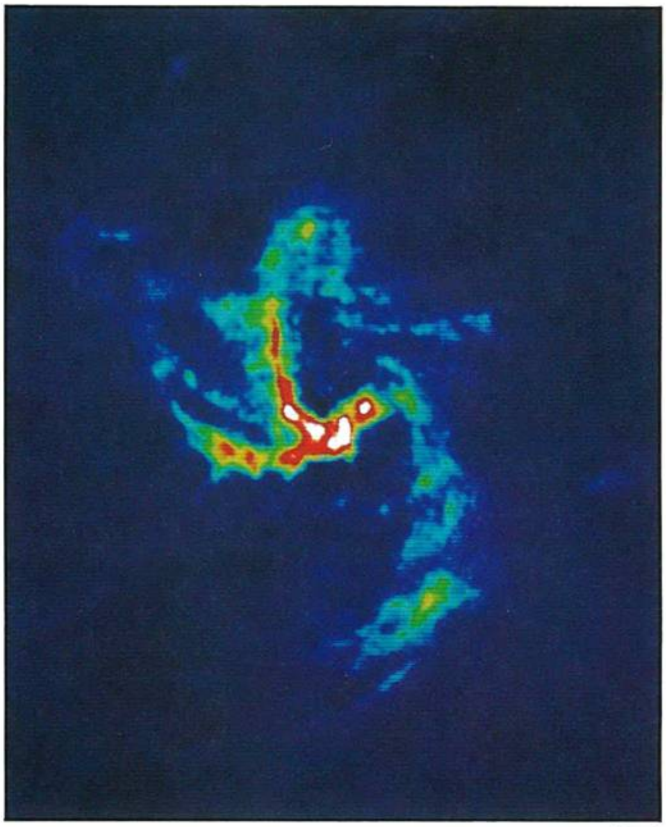
Discovery is nearly identical in construction to the other Space Shuttles; the only noticeable difference is the low-temperature thermal insulation that covers most of the orbiter. Instead of using the troublesome tiles that cover the other orbiters, *Discovery* features a patchwork of quilted silica fabric. This batting can be bonded directly to the Shuttle, saving weight, materials, and labor costs over the tiles, which required a felt pad between them and the orbiter to absorb stress.

Discovery is currently undergoing tests at Kennedy Space Center and is due to make its maiden flight this summer. *Atlantis* is scheduled for delivery to NASA at the end of this year. *Patty Winter.*

Amateur Space Telescope Nears Completion

Much of the construction work on the Amateur Space Telescope is nearing completion. The Independent Space Research Group (ISRG) of Troy, New York, hopes to have the complete system ready for flight in 1985. And although negotiations with NASA are still underway, the ISRG hopes to use a "Get-Away Special" on Shuttle Mission 14 this year as a test flight for many of the project's electronic and mechanical parts.

"Structural components are pretty much complete," said Jesse Eichenlaub, president of the 700-member ISRG. "The optics are designed." He added there is a good possibility that one of several interested parties will donate the 18-inch mirror for the satellite's telescope and camera system. Total cost for the satellite is expected to reach $100,000.



In mid-December, two Caltech astronomers used the VLA radio telescope to obtain this high-resolution view of the Galactic center's inner few parsecs. The map clearly shows three lanes of ionized gas, suggesting matter spiraling into a supermassive object. According to the astronomers, K.Y. Lo and Mark Claussen, the structure is evidence that a black hole resides in the center of the Milky Way.

Caltech

The Amateur Space Telescope, which is to carry a telescope into space for use by amateur astronomers, is being built by a team of about 30 students and a handful of faculty from Rensselaer Polytechnic Institute and the University of Rochester in New York. The entire satellite package will include television cameras, photometers, a small spectrograph, and the necessary control and communications hardware.

Although it won't be difficult for anyone on Earth to receive pictures and other data from the orbiting observatory when it is overhead, ISRG will control where it will be directed and which objects it will study. Potential observers must first submit proposals to the ISRG for approval, then the ISRG will schedule an approved project for time on the orbiting observatory.

"The AST will be a user-oriented instrument," says Eichenlaub. "We plan to work out a planetary patrol program, periodically watching for interesting weather phenomena on Mars and Jupiter at high resolution and bringing such phenomena to the attention of NASA's Space Telescope Center and others for a closer look." (NASA's Edwin Hubble Space Telescope, although not yet in orbit, will provide professional space scientists with a 92-inch instrument to study the heavens. It is now scheduled to be launched via the Shuttle sometime in 1986.)

Another project for the AST could be monitoring changes in the brightness of variable stars. Although amateur astronomers now provide most of the day-to-day work involved in this vigil, the AST could observe variables in ultraviolet wavelengths. It could also monitor stars that are fainter than those within reach of most Earth-based amateur telescopes.

Attitude control has been a major problem to overcome in the design of orbiting space observatories. Many of NASA's setbacks in the Space Telescope project have come about because of problems in developing a guidance system with enough accuracy to keep the telescope pointed in precisely the right direction. Otherwise the extremely fine figure of the 92-inch mirror cannot be used to its full limits.

The amateurs building the AST have designed a system of flywheels to solve the control problem. They will be mounted perpendicular to each other on magnetic bearings, with a fourth on hand as a backup. A microprocessor, working with the help of star sensors, will control the rotation of the flywheels, which will in turn control the movements of the AST.

Approximately 60 watts of electricity will be provided to the AST system from solar panels, which will unfurl to a five-foot wingspan after the satellite is launched from the Shuttle. A set of nickel-cadmium batteries will store electrical power. Two transmitters will send data back to ground stations on Earth. One will continuously broadcast telemetry; the other will beam back observational data and television pictures. The main body of the 175-pound satellite will consist of five identical shelves of platforms supported by a central column. Components will be mounted on the shelves, which will be made from sandwiched graphite-epoxy and Nomex nylon.

Satellites put together by amateur enthusiasts are not new. Amateur radio operators built their first communications satellite in 1961 and convinced NASA to put it on board a rocket bound for orbit. Within the past 20 years, amateur radio operators in at least four countries — the U.S., the Soviet Union, England, and Australia — have reportedly built more than a dozen such communications satellites.

Most of these amateur satellite projects in the U.S. have been carried out by groups such as the Radio Amateur Satellite Corporation. Representatives of these groups say that their satellites cost a mere 1% to 2% of what NASA would spend to build similar systems.

Why so great a difference? They say it's simply because amateur satellites make use of "off-the-shelf" and homemade parts and are put together with volunteer labor. Another significant savings comes when the satellites are put into space with piggyback rides on NASA launch vehicles.

For more information about the Amateur Space Telescope and the Independent Space Research Group, write the ISRG at P.O. Drawer 1246, Troy, NY 12180. *Ray Grasshoff.*

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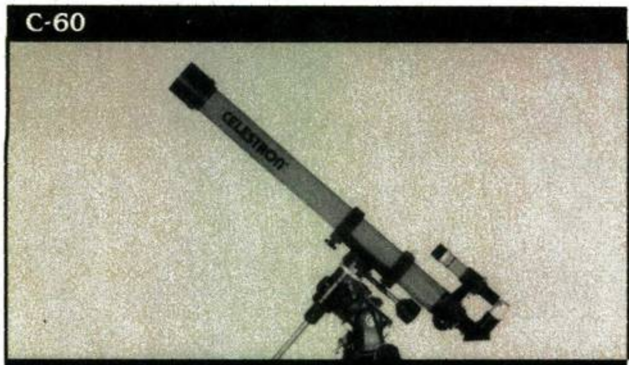

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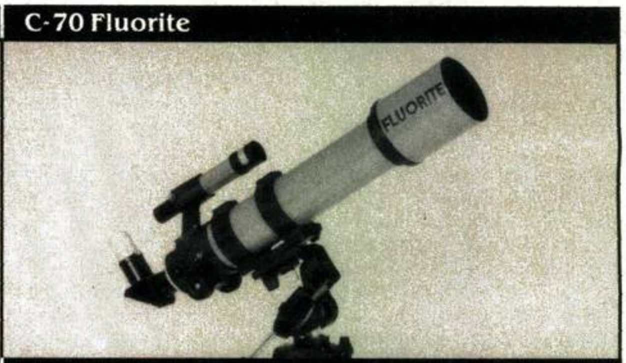

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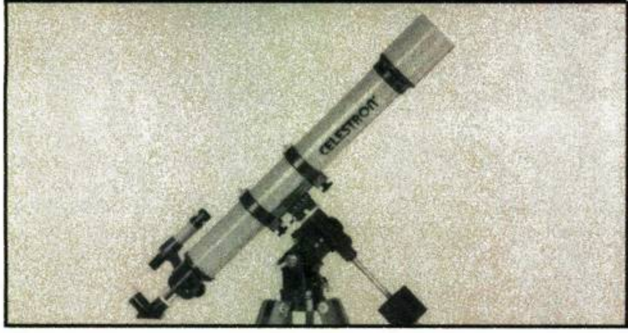

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ASTRO NEWS

International Halley Watch Updates —

- *How to pronounce it.* Should it be HAL-ee, HAWL-ee, or HAIL-ee? Well, it depends on whom you talk to. Old Edmond (observe the "o," please) himself spelled the surname in divers ways — as was customary in an era when English spelling had yet to harden into the rigid forms we observe today. In addition to the now-accepted spelling, you can also find it written as Hawley, Hayley, and Hally!

Although there is some precedent for pronouncing it as HAIL-ee (as those from the north of England now do), Edmond Halley came from the south of England. For most North Americans, HAIL-ee harks back most strongly to the early pop music group, Bill Haley and the Comets — a tenuous connection at best. Thus we can almost certainly dismiss HAIL-ee as incorrect.

It's not so easy to decide between HAL-ee and HAWL-ee. Ewen Whittaker, a planetary scientist who grew up in the same parts of England as Halley did, feels that the original pronunciation was probably HAWL-ee, but today this is the least common of the three ways to pronounce the name. According to a telephone survey of present-day Halleys living in London made by British author Nigel Calder, most pronounced their names to rhyme with "alley."

- *The "practice comet" returns.* Some time ago, the organizers of the International Halley Watch decided that it would help those involved in the program if they could test out techniques for observing Halley on another periodic comet; the one chosen was P/Crommelin, an object observed on four previous occasions (1818, 1873, 1928, and 1956) and due back at perihelion on February 20, 1984. P/Crommelin was recovered in mid-August 1983; its motions so far show that it will be close to its predicted peak magnitude of 6.4 (in early March). The trial run for Halley is scheduled for March 25 to 31, 1984, about five weeks after perihelion.

Anyone interested in joining the International Halley Watch should write to Stephen J. Edberg, Mail Stop T-1166, Jet Propulsion Laboratory, 4800 Oak Grove Dr., Pasadena, CA 91109 for further information.

Understanding Cosmic Fire

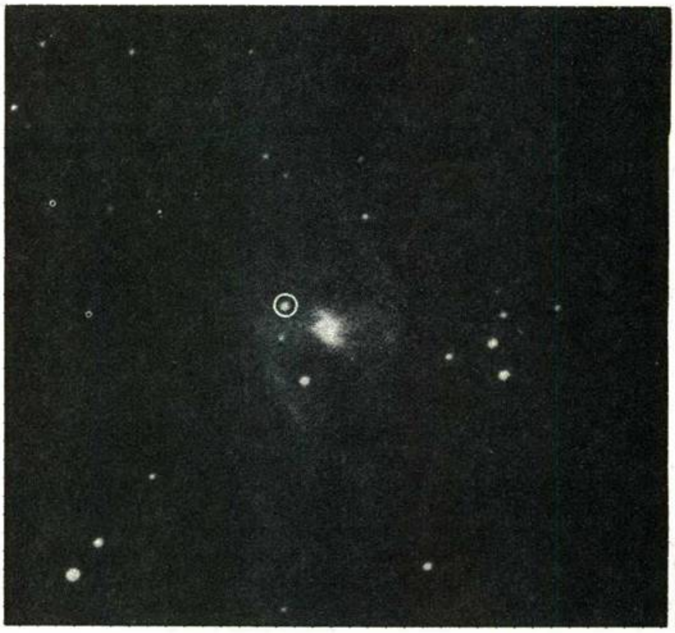
For years, physicists have argued whether quarks, the elusive fundamental particles believed to make up protons and neutrons, can exist without being bound to other quarks. Current theories maintain that such "free quarks" are impossible, that quarks must always come in groups of two or three. But physicists now suggest that extra quarks could bind to the nucleus of conventional atoms, creating nuclei with fractional charge. And these small, fractionally charged nuclei — if they exist — may give scientists a better idea of how the nuclear furnaces inside stars actually work.

In a paper recently published in the journal *Physical Review Letters*, a group of physicists at Ohio State University offered an explanation of the role such nuclei might play in stellar fusion. So far, the only evidence that fractionally charged nuclei exist is an experiment conducted in 1978 by researchers at Stanford University. Other researchers have not been able to duplicate the results of that experiment, so the findings of the Stanford physicists are still in question. Their results imply that one fractionally charged nucleus exists for every billion billion conventional nuclei. "They may well have slipped through our fingers," remarks Richard Boyd, an Ohio State physicist. "They could exist at that level and we just wouldn't see them." The sensitivity of his experimental attempt to verify the Stanford results was great enough but, he says, "we just might not have looked in the right place."

In their paper, Boyd and his colleagues assumed that fractionally charged nuclei do exist and may be found inside stars. The physicists were interested in what role such nuclei would play in nucleosynthesis, the production of heavy nuclei as a result of nuclear fusion occurring inside stars.

They looked at one standard set of reactions proposed for nuclear fusion in stars, the CNO (carbon-nitrogen-oxygen) cycle. In the CNO cycle, a proton combines with an isotope of carbon, carbon-12, to form the new isotope, nitrogen-13. The new isotope undergoes radioactive decay, releasing energy, and combines with another proton to form nitrogen-14; the process repeats, resulting in nitrogen-15. Still another proton tries to bind to the nitrogen-15 nucleus, but instead of forming an isotope of oxygen-16, as might be expected, the nucleus emits a helium nucleus and reverts back to the original carbon-12, completing the cycle.

Boyd's group suggests that a similar process could take place using elements other than those in the CNO cycle. If a particular additional quark — the "up" quark — binds to a helium nucleus, that nucleus would undergo a series of transformations through isotopes of helium, lithium, and beryllium before returning to the original helium nucleus.



Ronald Royer

In November, Robert Evans of Australia discovered his sixth supernova, a 14th magnitude object in galaxy NGC-1365, a member of the Fornax galaxy cluster.

If this did occur in nature, the reactions would take place at least a million billion times faster than those that make up the CNO cycle. Such speed would make it a viable contender for the process controlling nucleosynthesis, notes Boyd. "They [fractionally charged nuclei] could be very rare and still make a huge difference," he adds.

But for Boyd's mechanism to work, solitary quarks must have been left over after the Big Bang, the event that most scientists believe formed the universe as we know it. These quarks would give the fractional charge to the nuclei, and it's these quarks that the Stanford experiment allegedly detected. But if the results of the experiment are found to be incorrect, Boyd's theory will also fall. If all goes well, Boyd and his colleagues will run their own experiment next year at Ohio State in hopes of determining whether fractionally charged nuclei exist.

SETI Program Expanded

An ongoing search for extraterrestrial intelligence (SETI), organized and funded by the Planetary Society, has recently been expanded. Their program was already the most advanced SETI project currently operating, and the expansion, called META — for Megachannel ExtraTerrestrial Assay — will increase the project's coverage 64-fold.

The search has been running since March 7, 1983, when Paul Horowitz of Harvard University turned on the receiver, which is located at Harvard College Observatory's Oak Ridge radio telescope. Since then, the 84-foot dish antenna has probed the sky constantly, searching 131,000 channels simultaneously for artificial extraterrestrial radio signals. The new expansion, to be carried out during the coming year, will increase the scans to include 8.4 million channels at a time.

Horowitz says the expansion of the search "will make it the biggest analyzer on Earth. It will allow us to detect an extraterrestrial civilization that is not beaming a signal specifically to us." A physicist and electronics expert, Horowitz constructed the receiver.

The basic equipment was tested at the giant 1000-foot antenna in Arecibo, Puerto Rico, where it examined some 200 nearby Sun-like stars, searching for signals at special or "magic" radio frequencies. These are frequencies that would be known to other civilizations as well as ours, because the laws of nature are the same everywhere. Since these channels are distinctive, any artificial signal broadcast in them would stand out from the random radio noise of the Galaxy.

The program will continue for the next four years, with the 84-foot dish dedicated entirely to the search.

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ASTRO NEWS

ASTRO CALENDAR

March 3	**Seminar in Electronics-Oriented Astronomy,** Cypress College, Cypress, California. Sponsored by Orange County Astronomers. Contact (send SASE): Orange County Astronomers, 2215 Martha Ave., Orange, CA 92667. Phone John Sanford, (714) 639-8446 or Harry Miller, (714) 637-8870.
March 12-16	**Fifteenth Lunar and Planetary Science Conference** (professional meeting). Johnson Space Center, Houston, Texas. Contact: 15th LPSC, Lunar and Planetary Institute, 3303 NASA Road 1, Houston, TX 77058.
April 5-8	**National Meeting of the National Science Teachers Association,** Boston, Massachusetts. Contact: N.S.T.A., 1742 Connecticut Ave., Washington, DC 20009. Phone (202) 328-5800.
April 20-22	**Third Annual Conference on Space Development,** San Francisco, California. Sponsored by the L-5 Society. Contact: Charles Curley, Third Annual Conference on Space Development, 1275 Fourth St. #242, Santa Rosa, CA 95404. Phone (707) 538-1227.
May 5	**Astronomy Day.** For more information, contact: Gary Tomlinson, Astronomy Day Coordinator, Astronomical League, Chaffee Planetarium, 54 Jefferson S.E., Grand Rapids, MI 49503. Phone (616) 456-3985. The Astronomical Association of Northern California hosts Astronomy Day on April 7.
May 25-28	**Riverside Telescope Maker's Conference,** Big Bear, California. Contact: Cliff Holmes, 8642 Wells Ave., Riverside, CA 92505.
May 30-June 3	**Texas Star Party,** Fort Davis, Texas. Contact: TSP '84, Dept. A, 128 N. Commerce, Burleson, TX 76028.
July 7-12	**Joint Meeting of the Astronomical Society of the Pacific and the Western Amateur Astronomers,** University of California, Santa Cruz, California. Contact: Summer Meeting, A.S.P., 1290 24th Ave., San Francisco, CA 94122.
July 10-14	**Case for Mars II,** Boulder, Colorado. A workshop on the future of manned missions to Mars, sponsored by the Mars Institute of the Planetary Society, the Boulder Center for Science and Policy, and the University of Colorado Space Interest Group. Contact: Case for Mars, P.O. Box 4877, Boulder, CO 80306.
July 12-14	**Microcomputers in Astronomy II.** Fifth annual IAPPP-Fairborn Symposium, Fairborn, Ohio. Contact Russell M. Genet, Fairborn Observatory, 1247 Folk Rd., Fairborn, OH 45324.
July 16	**Florida Spaceweek '84.** State-wide celebration of the 15th anniversary of the Apollo 11 Moon mission. Contact: Florida Spaceweek Committee, 993 Macco Rd., Cocoa, FL 32927.
July 20-31	**International Workshop on Astrophotography,** Oteppe, Belgium. Limited to young amateur astronomers ages 16-24. Contact: Luc Vanhoeck, Belgian Astronomical Association (VVS) Section Astrophotography, Elsbos 16, B-2520, Edegem, Belgium.
July 28	**Stellafane,** Springfield, Vermont. Contact: Dennis di Cicco, 60 Victoria Rd., Sudbury, MA 01776.
August	**Sixth World General Assembly of International Union of Amateur Astronomers.** Bologna, Italy. Contact: Dr. Luigi Baldinelli, c/o A.A.B., Casella Postale 1630 AD, 1-40100 Bologna BO, Italy.
August 1-4	**ALCON '84,** National Convention of the Astronomical League. Carroll College, Waukesha, Wisconsin. Hosted by Milwaukee Astronomical Society. Contact: ALCON '84, P.O. Box 275, Mequon, WI 53092.
August 1-4	**Astromart '84,** an astronomy equipment fair held simultaneously with ALCON '84. Carroll College, Waukesha, Wisconsin. Hosted by ASTRONOMY Magazine. Contact: Dana-Lynne Terry, Advertising Coordinator, ASTRONOMY Magazine, P.O. Box 92788, Milwaukee, WI 53202. Phone (414) 276-2689.
August 6-10	**Spitz Space Systems' Summer Institute in Planetarium Education,** Chadds Ford, Pennsylvania. Contact: 1984 Planetarium Summer Institute, Spitz Space Systems, Inc., Route One, Chadds Ford, PA 19317.
August 17-18	**Near-IR and Solid-State Photometry Symposium,** Lowell, Michigan. Hosted by IAPPP and Optec. Contact: Russell M. Genet, Fairborn Observatory, 1247 Folk Rd., Fairborn, OH 45324.

Meeting notices to appear in AstroCalendar must be submitted at least four months in advance of the meeting date. Most organizations appreciate your enclosing a long (business-size) self-addressed, stamped envelope along with your request for information.

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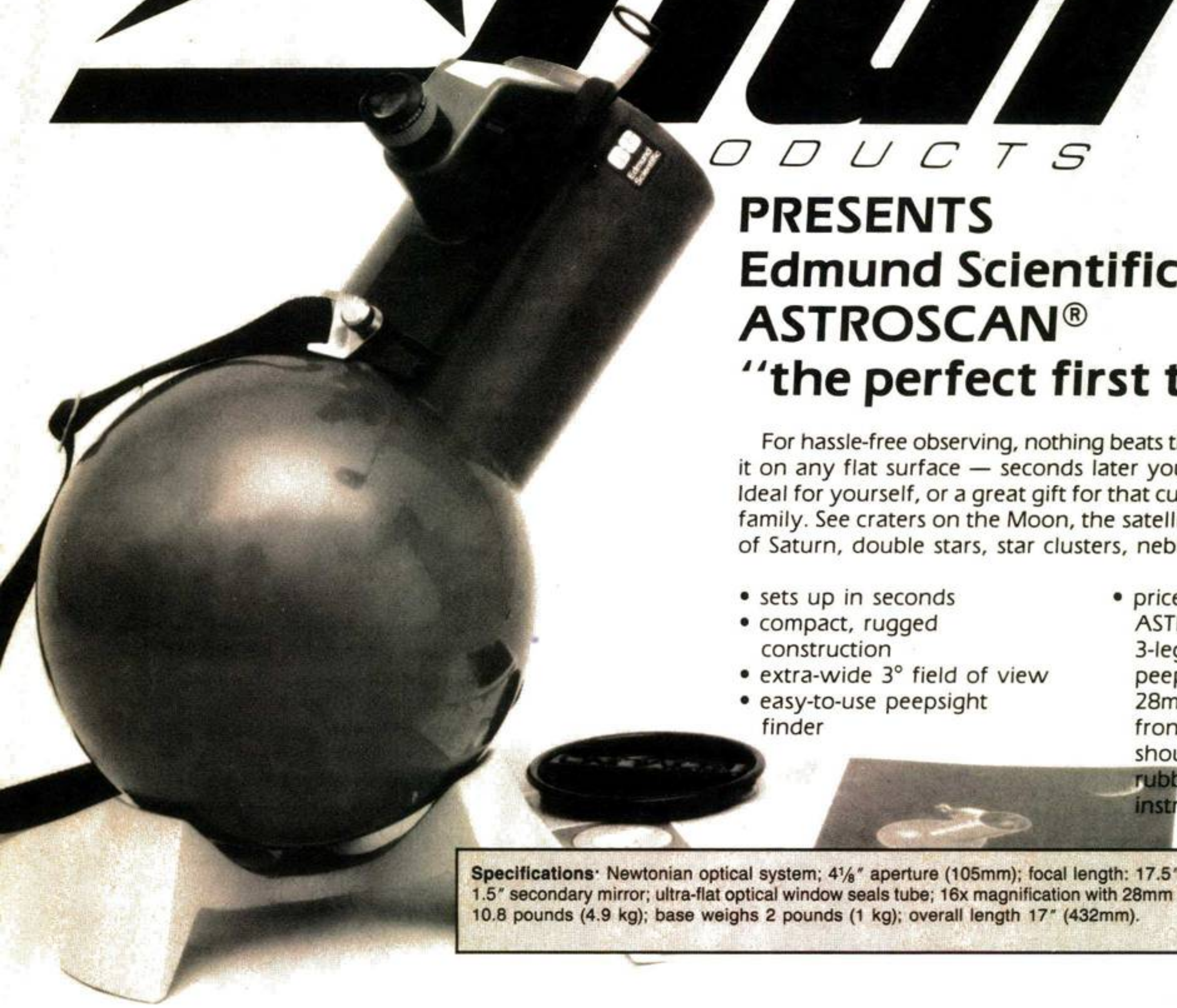

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The PLANCK ERA

by
Sten Odenwald

The Big Bang theory claims that the entire universe was created in a tremendous explosion about 20 billion years ago. The enormity of this event is hard to grasp, and it seems natural to ask ourselves, "What was it like then?" and "What happened before the Big Bang?" If we could take a brief journey backward in time, we would first see the formation of our own Sun about 5 billion years ago, or 15 billion years after the Big Bang. As we pass back through the eons, we would watch the formation of the first galaxies about 5 billion years after the explosive birth of the cosmos. Moving farther back in time, the universe 700,000 years after the Big Bang would be awash with radiation that keeps all matter at a temperature of 4,000° Kelvin. Because of this, there is no darkness in the cosmos — every point in the sky glows with the brilliance of the Sun. No stars, planets, or even dust grains exist — just a hot, dense plasma of electrons, protons, and helium nuclei.

Only three minutes after the Big Bang, we would see helium form from the fusion of hydrogen atoms in a universe seething at a temperature of nearly one billion degrees. At this point, the matter in the cosmos is, on the average, as dense as lead. Moving beyond the one-second mark, past the beginning of the Era of Leptons (particles like electrons and neutrinos), the universe would hold a fixed ratio of nuclear particles: one neutron to every five protons. This is the Era of Quarks; throughout the universe, the temperature is now five billion degrees. We would enter the Quark Era around 0.001 (10^{-3}) second after the Big Bang; the temperature of the fireball's radiation rises to an incredible one trillion degrees. This was the first period in the universe when the quarks could combine in pairs and trios to become neutrons, protons, and other types of heavy particles. The universe is now as packed with matter as the nucleus of an atom — the mass of Mount Everest could be squeezed into a volume no greater than that of a golf ball. By one billionth of a second after the explosion — at a temperature of one *thousand* trillion degrees — we would see two of nature's fundamental forces, the electromagnetic and weak nuclear interactions, merge into one. The universe would be so dense that the mass of the entire Earth could be contained in a thimble. Quarks and anti-quarks are no longer confined inside particles like neutrons and protons but are part of a superheated plasma of free particles.

Now, as the beginning of the universe unfolds before us and we come ever closer to the moment of the Big Bang, we pass through a "long" period when nothing really new seems to happen. Then, at 10^{-35} second after the Big Bang, we would witness a spectacular change in the size of the universe. This is a period understandable only through the Grand Unification Theories (GUTs) of modern physics — the GUT Era. (See "The Decay of the False Vacuum," ASTRONOMY, November 1983.) Another fundamental force, the strong nuclear interaction, merges with the combined electromagnetic and weak nuclear forces. It is this merger that causes the abrupt change in the size of the cosmos. The temperature is an incredible 10,000 trillion trillion degrees and the density of matter has soared to nearly 10^{75} times that of water — a number so enormous that even our analogies are almost beyond comprehension. At this density, the entire Milky Way Galaxy could easily be stuffed into a volume no larger than a single hydrogen atom! Electrons and quarks, together with their anti-particles, are the major constituents of matter. Some very massive particles, called *leptoquark bosons*, cause quarks to decay into electrons and vice versa.

The GUT Era represents a period when the vacuum of space underwent a "phase transition" from a higher energy state to one of lower energy. This is analogous to a ball rolling down the side of a mountain and coming to rest in the lowest valley. As the universe "rolled downhill," it began a brief but stupendous period of expansion. The universe swelled to billions of times its former size in almost no time at all. In addition, there appeared a slight excess of matter over anti-matter. This was due to the decay of another massive particle called the *X Higgs boson*. As the universe aged, particles and anti-particles annihilated each other and vanished in a tremendous burst of energy. From this paroxysm was born the bulk of the fireball radiation that we now observe — the 3° K "background noise" of the universe.

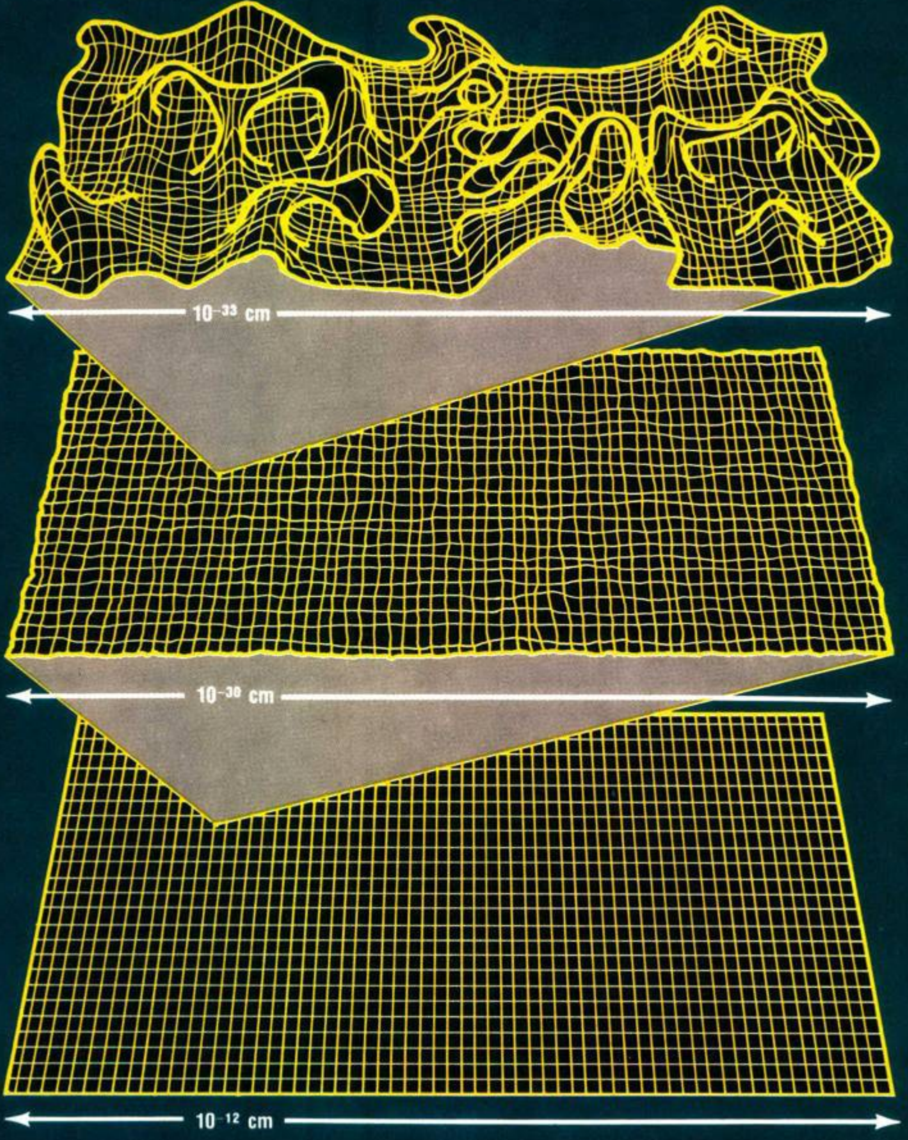
The GUT Era is the last stop on our fanciful journey through time. If we attempt to travel still farther back, to find out what went on before the GUT Era, we would immediately enter a vast no man's land — there are very few indisputable facts to guide us. It does seem clear, however, that the weakest force of the universe — gravity — will grow more important as we probe our way back to the Big Bang. In fact, gravity should eventually become the dominant force between particles, even at the microscopic level.

Gravity

According to theories developed since the 1930s, what we call a "force" is actually a collective phenomenon caused by the exchange of innumerable force-carrying particles called *gauge bosons*. There are four basic forces in the universe, each one carried by a specific gauge particle. The electromagnetic force, which causes like charges to repel and dissimilar ones to attract one another, is "transmitted" by gauge bosons called *photons*. The strong force that binds nuclei together is carried by gauge bosons called *gluons*, while the weak force, which causes the decay of unstable nuclei, is transmitted by the recently discovered *intermediate vector bosons*. Similarly, physicists believe that particles called *gravitons* carry gravity. If gravity really does have this quantum property, we should be able to see its effects once quarks and electrons can be forced to within 10^{-33} centimeter of one another, a distance called the *Planck length*. To achieve these conditions, quarks and electrons must collide at energies of 10^{19} GeV, equivalent to their motions in a gas at a temperature of 10^{32}°K. A linear particle accelerator of today's technology would have to be the size of the Milky Way Galaxy to push particles to these incredible energies! Fortunately, what humans find impossible to do, nature finds less difficult. Before the universe was 10^{-43} second old, matter routinely experienced such energetic collisions. This brief period just after the Big Bang is what we call the Planck Era.

Through a Looking Glass, Darkly

Since our technology will not allow us to reproduce the physical conditions during these ancient times, we must use our mathematical theories of how matter behaves to explore the early universe. We know that the appearance of the universe before 10^{-43} second can only be described adequately by modifying the Big Bang theory, which was itself based on Einstein's general theory of relativity. General relativity tells us how gravity operates on the macroscopic scale of planets, stars, and galaxies. At the Planck scale, we must extend general relativity so that it includes not only the macroscopic properties of gravity, but its microscopic characteristics as well. This theory of "quantum gravity" is still far from complete, but physicists agree that, at the very least, quantum gravity must combine the conceptual elements of the two great theories of modern physics: general



At the Planck scale, a billion trillion times smaller than the nucleus of an atom, the geometry of space continually undergoes violent fluctuations.

Space looks slightly choppy at a scale 1,000 times larger than the Planck length.

In the atomic realm, however, the chaotic fluctuations are completely undetectable. Space appears very smooth.

relativity and quantum mechanics.

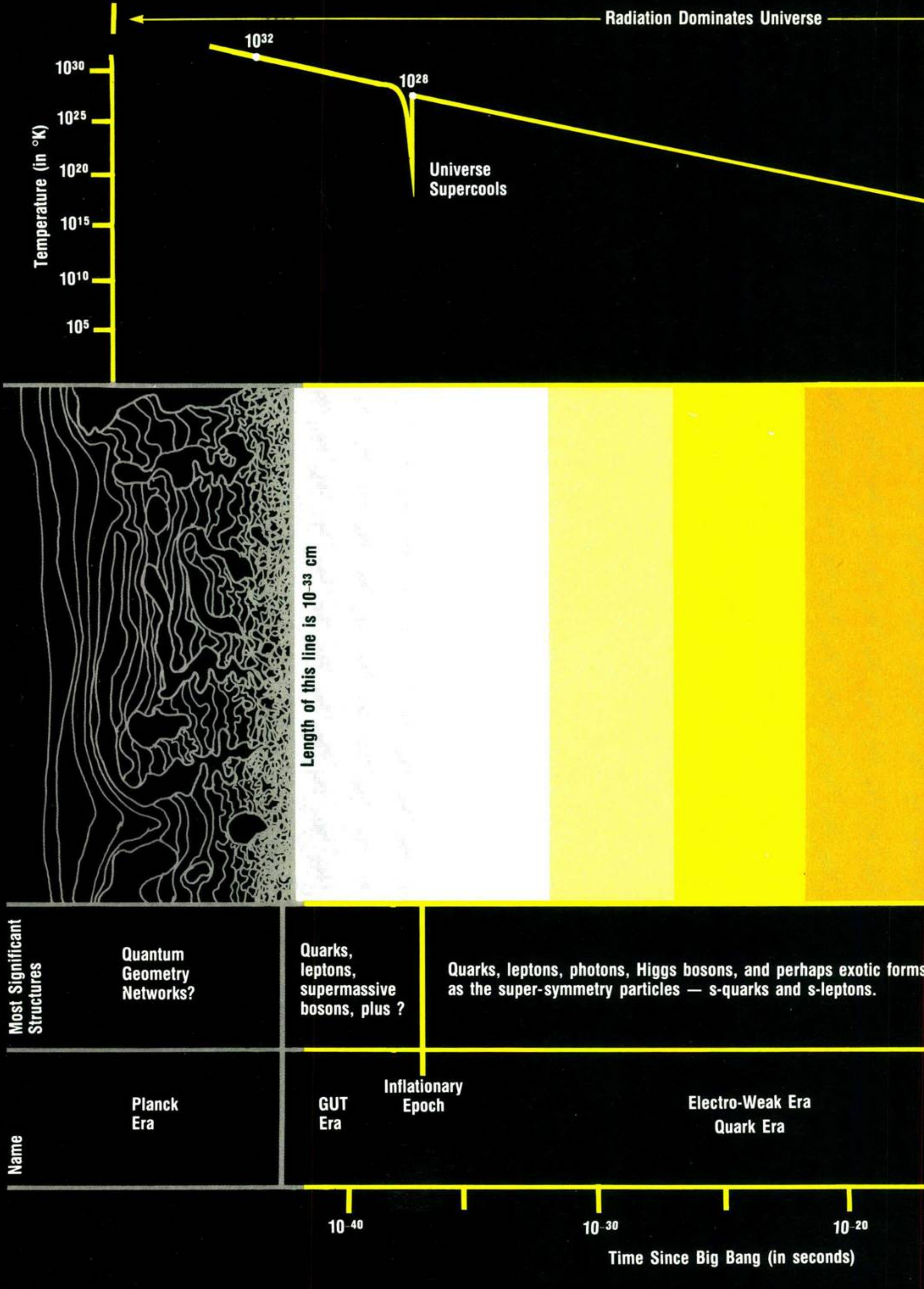
In the language of general relativity, gravity is a consequence of the deformation of space caused by the presence of matter and energy. Gravity is just another name for the degree of curvature in three-dimensional space. In quantum gravity theory, gravity is produced by massless gravitons — gravitons represent individual "packages" of curved space that travel at the speed of light.

The appearance and disappearance of innumerable gravitons give the geometry of space a lumpy, ever-changing appearance. John A. Wheeler, a physicist at Princeton University, thinks of it as a foamy sub-structure where the geometry of space twists and contorts — far-flung regions of the universe may suddenly find themselves connected by "wormholes" that appear and disappear within 10^{-43} second. Even as you read this article, the hyper-microscopic domain — 100 billion billion times smaller than the nucleus of an atom — is undergoing frenetic activity. For a comparison, the difference in size between an atom and the domain of the graviton is proportionally the same as that between the Sun and an atom. The effects of quantum gravity are completely undetectable today at the atomic and nuclear scale. But during the Planck Era, the macroscopic and microscopic worlds merged — the quantum gravity of the microcosm became the quantum cosmology of the macrocosm.

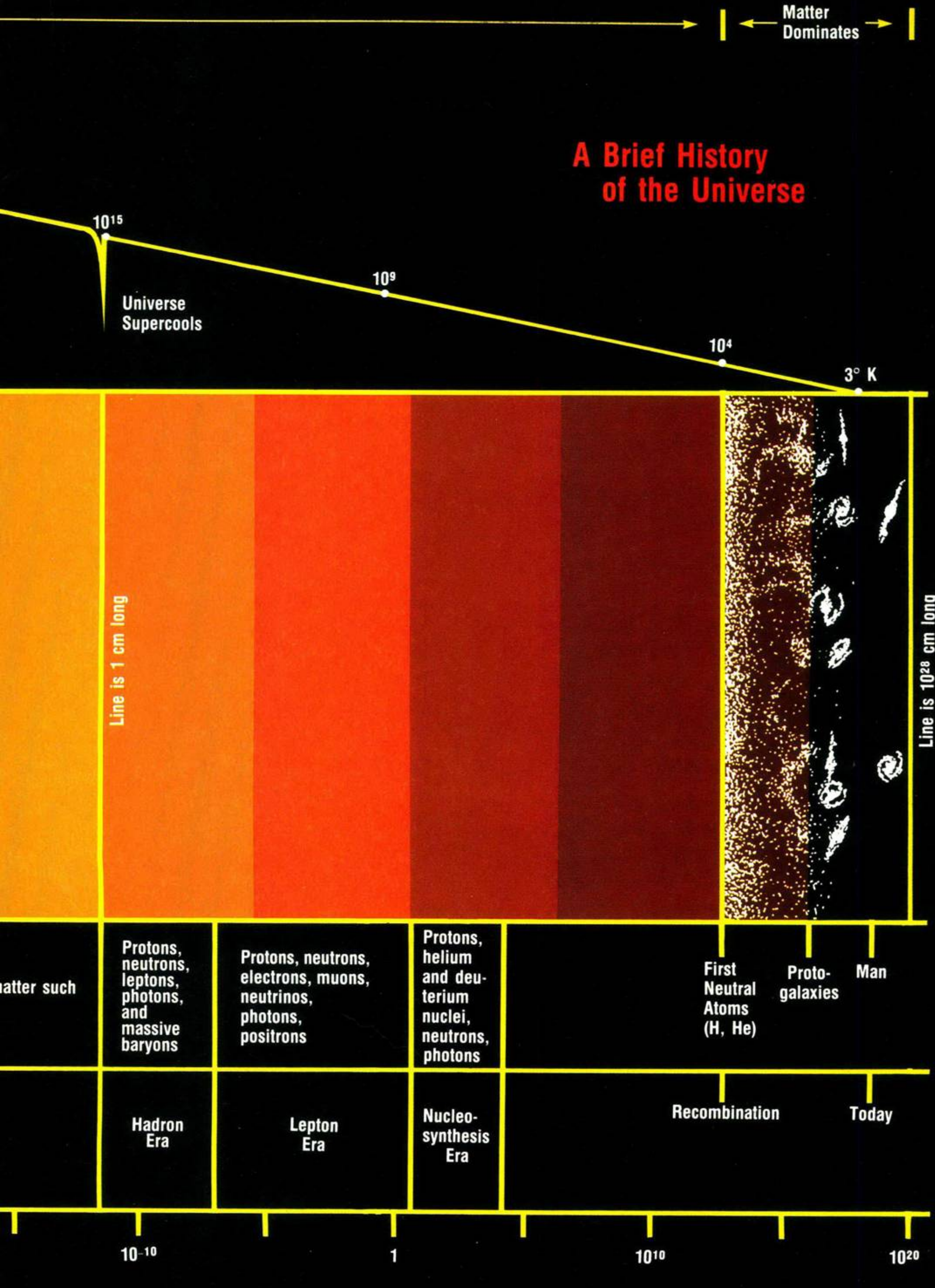
Quantum Cosmology

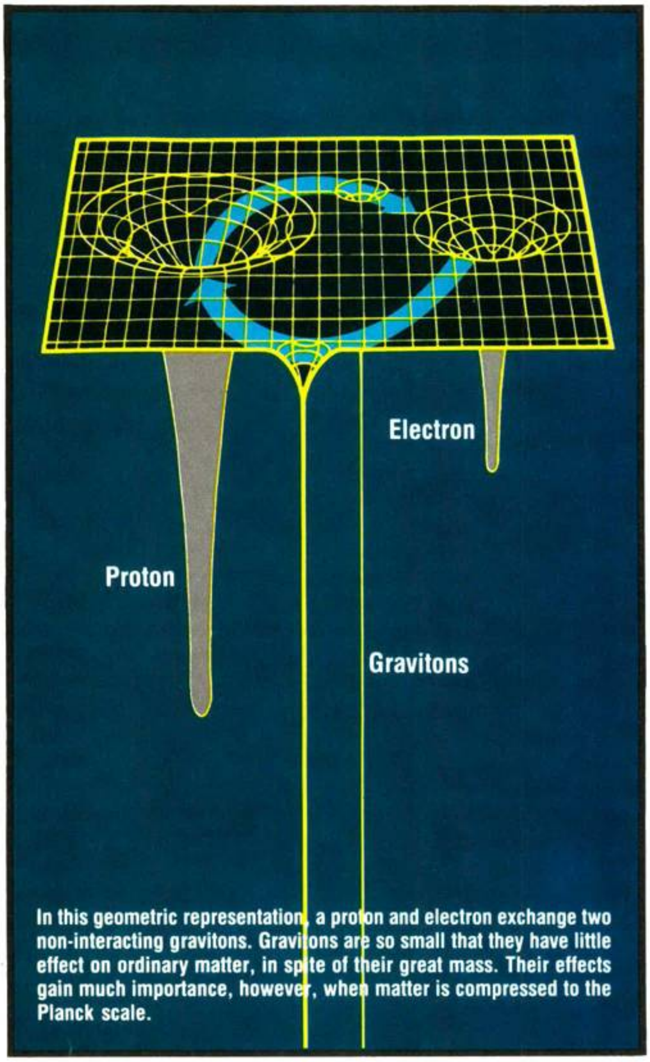
What went on in the Planck Era? Let's again journey backward through time. As we approach the end of the Planck Era, about 10^{-43} second after the Big Bang, the random appearance and disappearance of innumerable gravitons will eventually force us to give up the concept of a specific "shape" to three-dimensional space. Instead, its geometry at a given moment must be thought of as an *average* over all possible geometries of three-dimensional space. The reason: Particles are squeezed so close together that we can now see the effects from individual gravitons curving the space between them.

Today we say that the space between two quarks is flat, and that gravity is the weakest of the fundamental interactions. We can say these things because the distance between two quarks is so huge in comparison to the Planck scale of 10^{-33}cm; the gravitational attraction between two quarks is now insignificant


Radiation Dominates Universe
Temperature (in °K)
10^30
10^25
10^20
10^15
10^10
10^5
10^32
10^28
Universe Supercools
Length of this line is 10^-33 cm
Most Significant Structures
Quantum Geometry Networks?
Quarks, leptons, supermassive bosons, plus ?
Quarks, leptons, photons, Higgs bosons, and perhaps exotic forms
as the super-symmetry particles — s-quarks and s-leptons.
Name
Planck Era
GUT Era
Inflationary Epoch
Electro-Weak Era
Quark Era
10^-40
10^-30
10^-20
Time Since Big Bang (in seconds)

A Brief History of the Universe


Matter Dominates
10¹⁵
Universe Supercools
10⁹
10⁴
3° K
Line is 1 cm long
Line is 10²⁸ cm long
atter such
Protons, neutrons, leptons, photons, and massive baryons
Protons, neutrons, electrons, muons, neutrinos, photons, positrons
Protons, helium and deuterium nuclei, neutrons, photons
First Neutral Atoms (H, He)
Proto-galaxies
Man
Hadron Era
Lepton Era
Nucleosynthesis Era
Recombination
Today
10⁻¹⁰
1
10¹⁰
10²⁰



In this geometric representation, a proton and electron exchange two non-interacting gravitons. Gravitons are so small that they have little effect on ordinary matter, in spite of their great mass. Their effects gain much importance, however, when matter is compressed to the Planck scale.

because the space between them is so great. During the Planck Era, however, matter was packed so tightly that the effects of individual gravitons became noticeable.

To make matters worse, quantum gravity not only keeps us from calculating the exact three-dimensional geometry of space but, at the Planck scale, keeps us from knowing simultaneously both the exact geometry of space and just how that geometry changes as time goes on. This means that we may *never* be able to calculate with any certainty the exact history of the universe prior to 10^{-43} second after it began. Today, the large-scale geometry of space is one of three possible types: flat and infinite, negatively curved (saddle-shaped), and infinite or positively curved (spherical) and finite. During the Planck Era, wormholes contorted the large-scale geometry of space and an infinite number of types were possible. Probing the history of the universe during the Planck Era would be like trying to trace your ancestral roots if any human being on Earth might have been one of your parents. Then try to trace back your family tree a few generations! The further back in time you go, the greater the number of possible ancestors you could have had. Physicists will have to develop an entirely new conception of what is meant by the phrase "a history of the universe." Even our concepts of space and time will have to be completely re-evaluated in the face of the quantum fluctuations of space-time in the Planck Era.

The Birth of the Universe

So what went on in the Planck Era? What is its importance to cosmology? Here's the picture that emerges from our sketchy outline of what quantum gravity theory might look like. As we approach the Planck Era on our journey backward through time, quarks and electrons exchange gravitons with increasingly higher energy and in greater number. By the time we reach the end of the Planck Era at 10^{-43} second, gravitons begin to carry as much energy as the other force-carrying particles (gluons, photons, and intermediate vector bosons). At still earlier times, all of the natural forces would be unified — that is, the four fundamental interactions would be indistinguishable from one another. Only one force would exist in that universe — gravity — and only one kind of particle would dominate the activity of this age — gravitons.

During the early 1970s, the Russian physicists Ya. Zel'dovitch and A. Starobinski of the Soviet Union's Academy of Science proposed that the changing geometry of space during the Planck Era may actually have created all the matter, anti-matter, and radiation that exists. In their picture of Creation, the rapidly changing geometry of space created massive particles and anti-particles. The production of matter and anti-matter removed energy from the enormous fluctuations occurring in the geometry of space and, by the end of the Planck Era, succeeded in damping them out altogether. Their calculations also showed that the rate of particle creation increased as more and more particles were created.

Several recent studies by physicists Edward Tryon of Hunter College, R. Brout, F. Englert, and E. Gunzig of the University of Brussels, and David Atkatz and Heinz Pagels of Rockefeller University have shed additional light on the Big Bang. Imagine, if you can, nothing at all — this is the primordial vacuum of space. There is complete darkness here; no light yet exists. The number of dimensions to space was probably not the normal three that we are so accustomed to, and may have been as high as 11. In this infinite emptiness, random fluctuations in the very geometry of space ever so slightly changed the energy of the vacuum at various points. Eventually, one of these fluctuations attained a critical energy and began to grow. As it grew, the massive leptoquarks and anti-leptoquark particles were created; expansion accelerated, creating still more leptoquarks. This furious cycle continued until, at long last, the leptoquarks decayed into quarks, leptons (particles like electrons and muons, for example), and their anti-particles. Thus the universe emerged from the Planck Era, 10^{-43} second after its birth. Particle creation stopped once the fluctuations in the geometry of space subsided.

So we are left with the remarkable possibility that, in the beginning, there existed nothing at all, and that nearly all of the matter and radiation we now see emerged from it. This process has been described by University of California physicist Frank Wilczyk: "The reason that there is something instead of nothing," he says, "is that 'nothing' is unstable." A ball sitting on the summit of a steep hill needs but the slightest tap to set it in motion. A random fluctuation in space is apparently all that was required to unleash the incredible latent energy of the vacuum, creating matter and energy and an expanding universe from, quite literally, nothing at all.

The universe did not spring into being instantaneously, but was created a little bit at a time. Once a few particles were created by quantum fluctuations of the empty vacuum, it became easier for a few more to appear, and so forth. In a rapidly escalating process, the universe gushed forth from nothingness. How long did this take? The primordial vacuum could have existed for an eternity before the particular fluctuation that gave rise to our universe occurred. Or, as physicist Edward Tryon puts it, "Our universe is simply one of those things that happens from time to time."

The principles of quantum gravity may ultimately force us to reconsider questions like "What happened before the Big Bang?" Perhaps the complete theory of quantum gravity will tell us how to ask the *right* questions.

Sten Odenwald, an infrared astronomer, currently works at the Naval Research Laboratory. His research interests include studies of the far-infrared properties of giant molecular clouds and young star-forming regions in the Galaxy. His last article for ASTRONOMY *was "The Decay of the False Vacuum," November 1983.*

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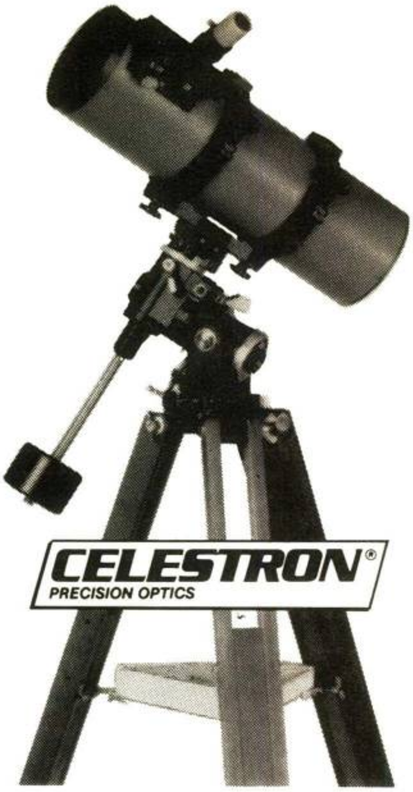

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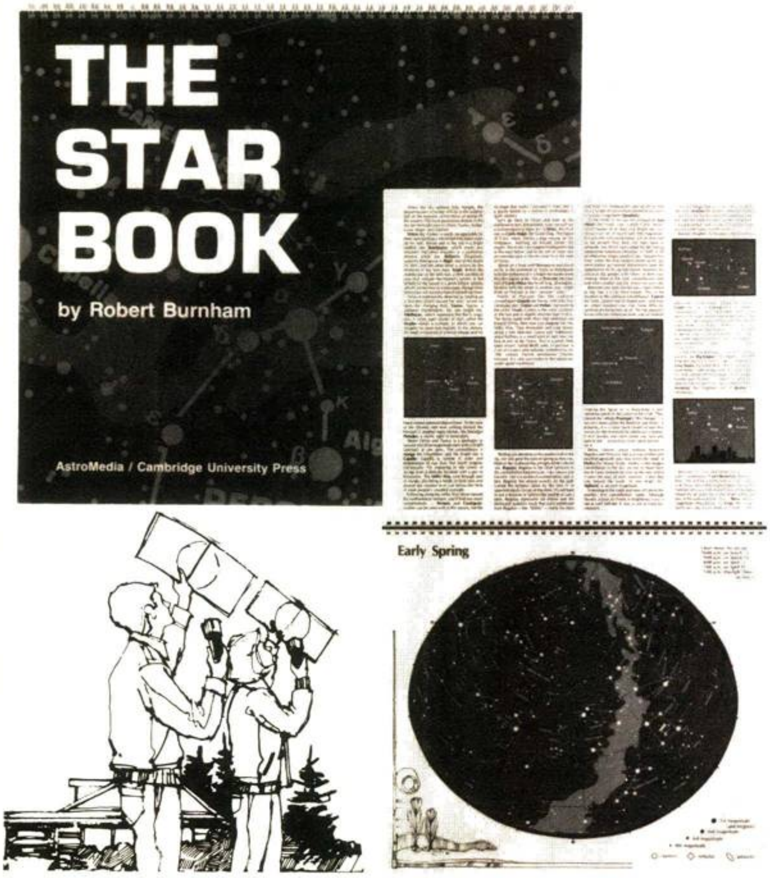

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Dixon Spacescapes	73
Fujinon	75
Hake's Americana	73
Lumicon	50,56
Meade Instruments	2-3
Meteorites	74
New England Astro. Optics	72
Optron	75
Orion	55
Quasar Optics	41
Scope City	73
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Univ. of Kansas	73

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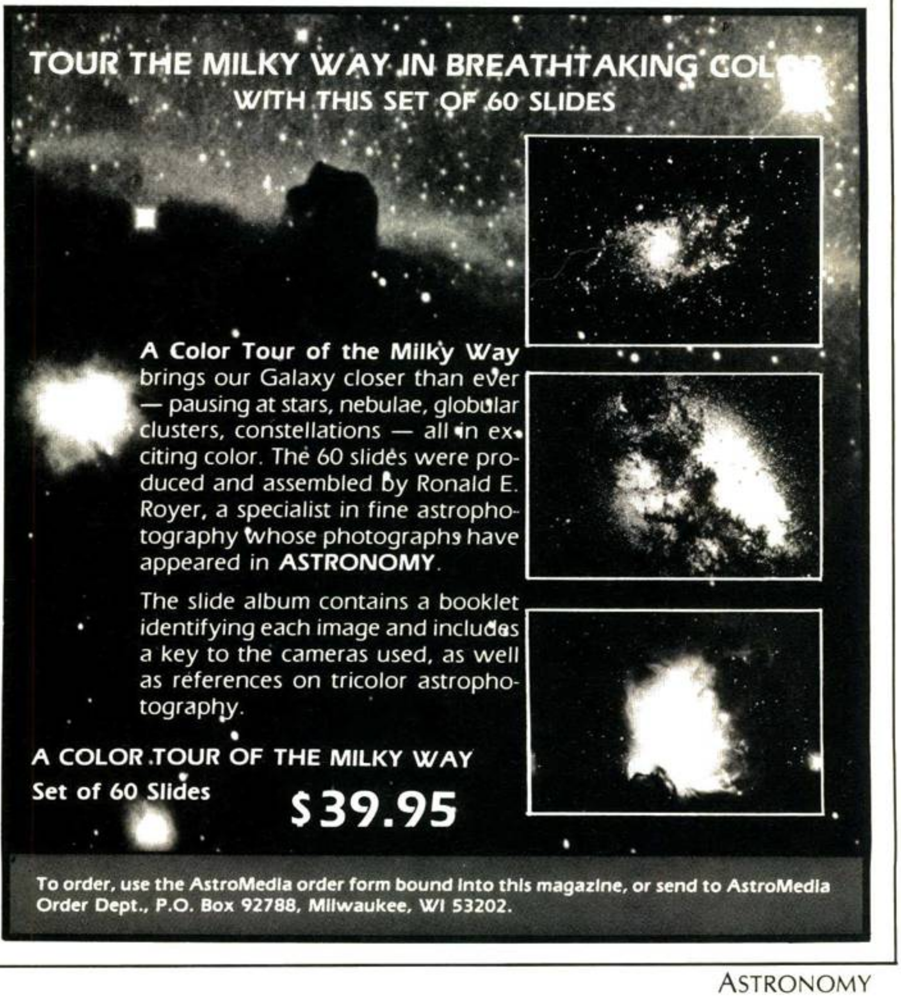

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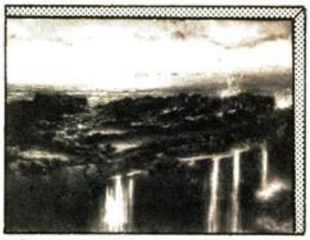

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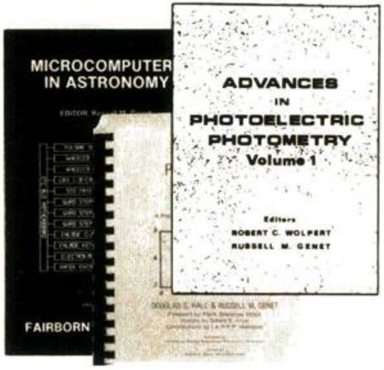
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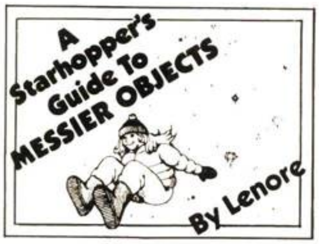

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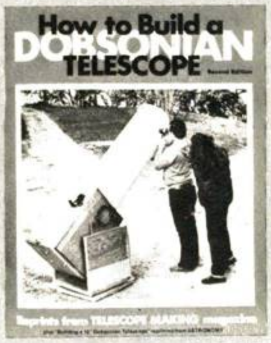

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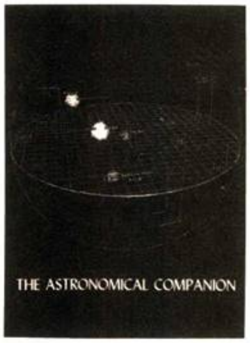
by Guy Ottewell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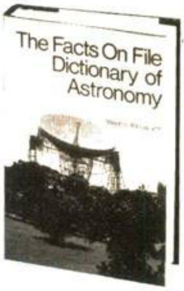

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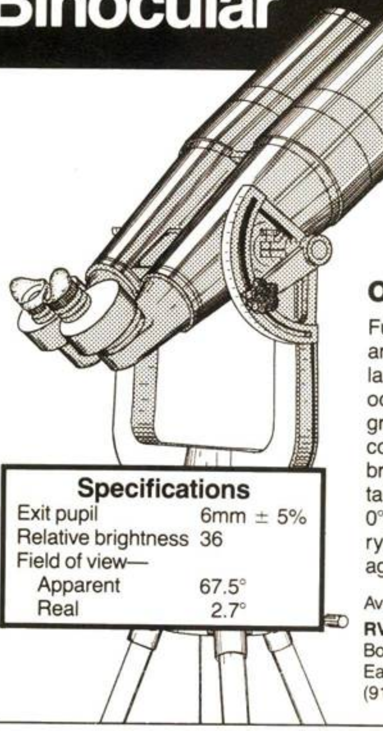

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FUJINON

A Homemade Finder Scope Mount

by Randall Wehler

How many times have you paged through a catalog of telescope equipment only to find that the item you want is much more expensive than you expected? While precision parts, such as optical components, might best be left for commercial telescope companies to produce (or for experienced amateurs to build), this isn't the end of the story. Some accessories require only a little ingenuity and not much experience, and can be built in the most modest garage or basement workshop. A short while ago, I felt that I needed an easily detachable finder scope mount for my 4-inch equatorially mounted refractor, and I eventually became confident enough to try building it, even though I had little experience in a workshop.

This 4-inch refractor has performed well. But I wanted a better finder — something over and above the 5 x 24 finder supplied with the scope. As many a small-telescope user can testify, a 5 x 24 finder is O.K. for locating bright objects, such as the Moon, planets, and prominent deep-sky objects, but it lacks the light-gathering ability needed to show the really faint objects you'll eventually want to find.

I had a good 40 mm spotting scope, which I calculated would provide 2.8 times more light-gathering power than the finder furnished with the telescope. This scope would allow me to find some of the faint objects that had eluded me before. But for several reasons, I did not want to drill holes in my telescope or mar the tube's surface. I wanted to attach the 40 mm spotting scope as a finder in such a way that I could easily detach it in the future as my observing needs changed.

After searching various hardware, tool, farm and home supply, and industrial parts stores, I happened upon the ideal components for a cheap, easy-to-build finder mount. The main parts are a pair of 4-inch diameter truck muffler clamps, available for under $6, and a bearing retainer or housing unit, obtainable for about $2. The only other components were a protective strip (to go between the telescope tube and muffler clamp), three small bolts, and four larger nuts (see the parts list). All of these incidentals are available at little cost from most hardware stores.

The only drilling I had to do was through the bearing retainer, so that it would accommodate three threaded centering screws spaced 120° apart. Locating them was easy with a protractor. Next I drilled holes with an electric drill, then cut threads with a tap and tap wrench. To allow space for turning the bottom centering screw, I inverted the lower piece of the bearing retainer. This gave me enough room to turn the hexagonal bolt head by inserting a wrench. Since there were enough threads on the ends of the U-shaped muffler clamp, I could screw on several nuts below the bearing retainer to control the height of the finder scope above the main tube.

PARTS LIST

(makes 2 mounting assemblies)

2	4″ diameter muffler clamps (includes two ⅜″ nuts)
2	3″ diameter bearing retainers or housing units (in two pieces), with bolting holes on ends separated by 4″
4	1/4″ 28-thread bolts, 1″ length
2	1/4″ 28-thread bolts, ¾″ length
8	3/8″ nuts, threaded same as muffler clamp U-bolt nuts
2	12½″ woven fabric strips, 1″ wide

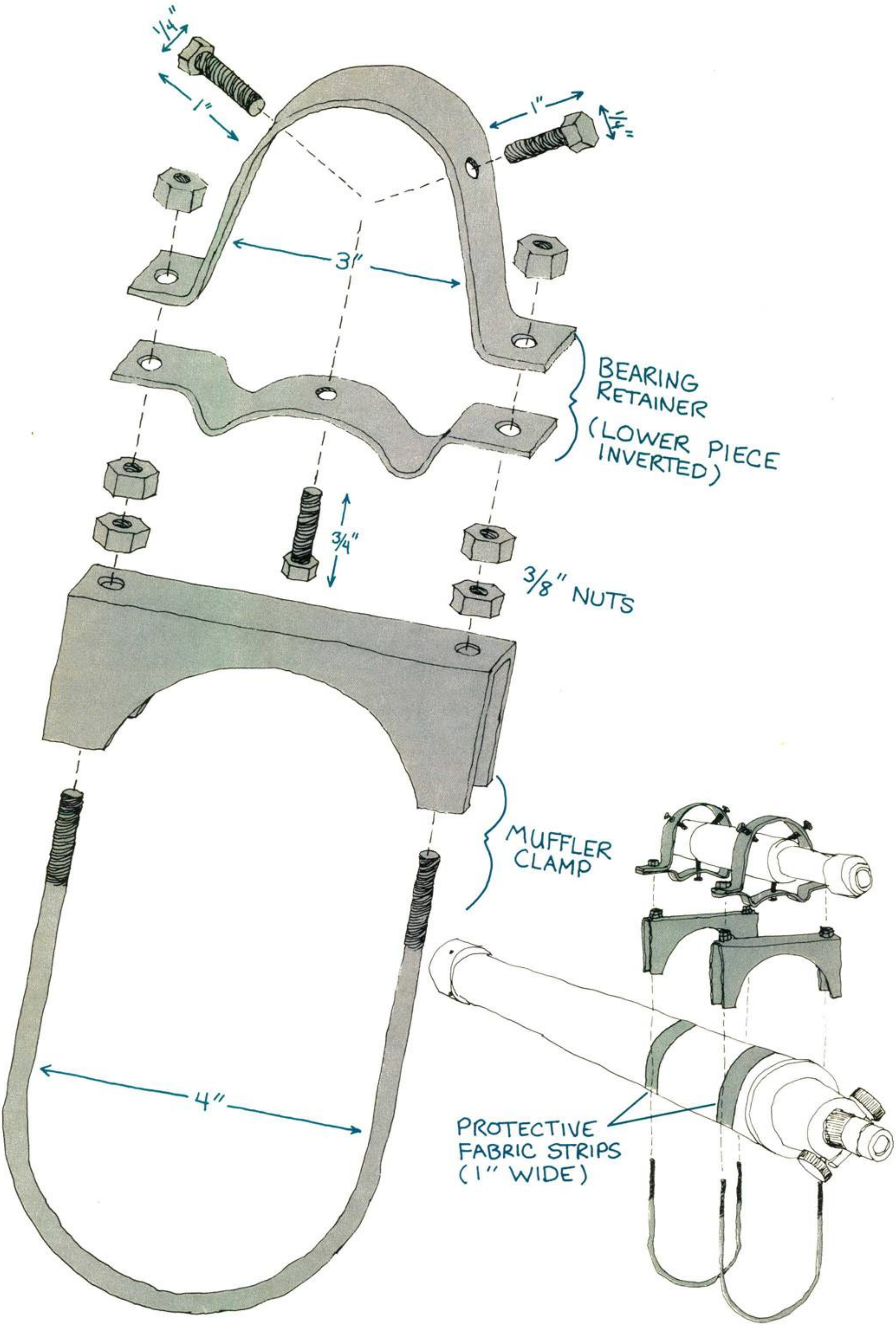
The added weight of the parts and new finder proved no real problem for the telescope's balance and maneuverability. Of course, to balance the tube properly, I had to move it forward, using the adjustable cradle straps. This provided a somewhat higher observing position for both straight-through and star-diagonal viewing — a welcome reduction of "crouching time"! The new finder scope was positioned on the main telescope tube with the rear mounting assembly back far enough so that the finder eyepiece was a little bit in front of the main eyepiece. I found this saved time in switching between finder and main tube viewing. I've kept the original 5 x 24 finder on the tube in an out-of-the-way position, where it is still usable as a secondary finder.

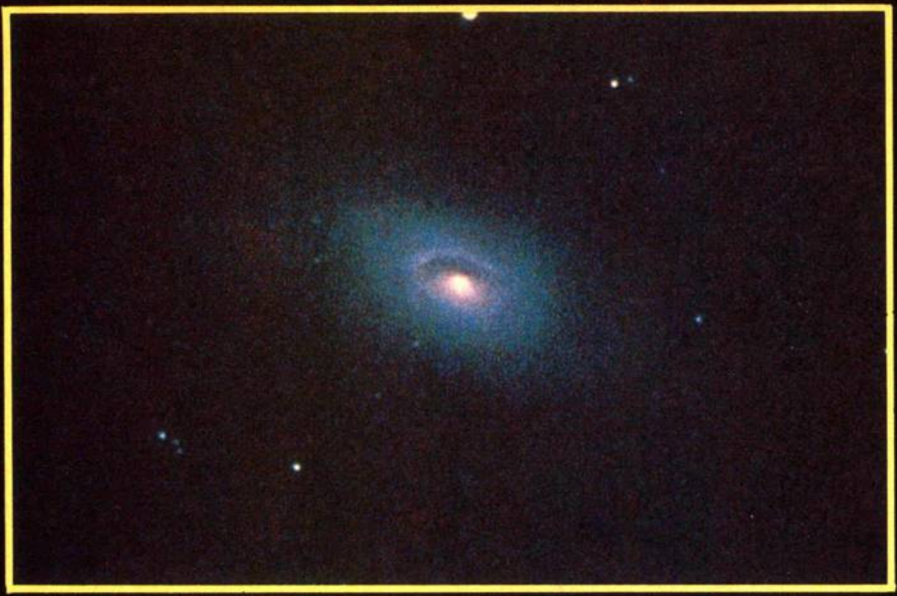
The only drawback to the spotting scope is that it provides an upright, correctly oriented image, contrary to the view in astronomical telescopes. But if you haven't yet adjusted to the inverted image, the upright view makes locating objects with star maps a little easier.

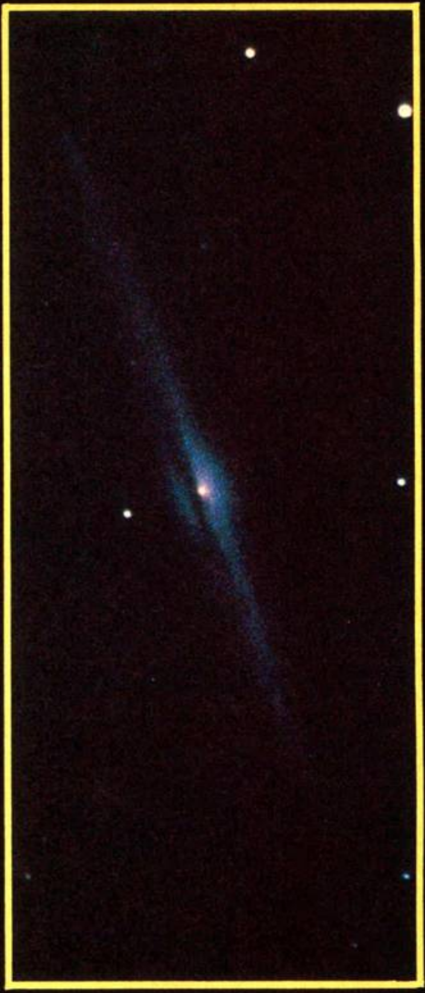
The parts I've listed are those used for my 4-inch telescope. But since muffler clamps and bearing housings come in a variety of sizes, you can get the right combination of parts for most other standard refractors and for small reflectors. In addition, when I measured the bearing retainer, which holds the centering screws, I found that it could accommodate somewhat larger finders.

In a year's observing with this particular instrument, I never added any accessories to it, but assembling this finder was so easy that I'll probably tackle other projects. I'll readily admit that commercially produced telescope parts and accessories are machined and built with precision far above the capabilities of most amateur astronomers. But, believe me, nothing surpasses the pleasure, satisfaction, and savings of making your own!

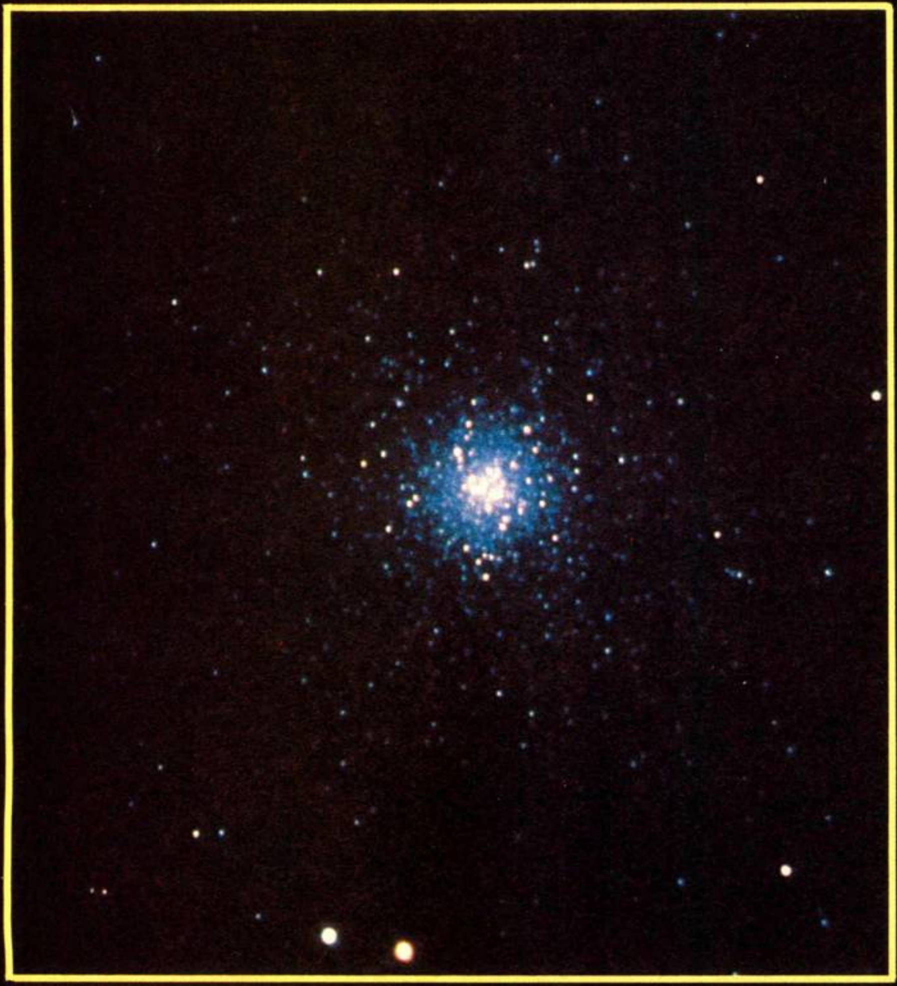
Randall Wehler, a psychologist, has been an amateur astronomer for two years.

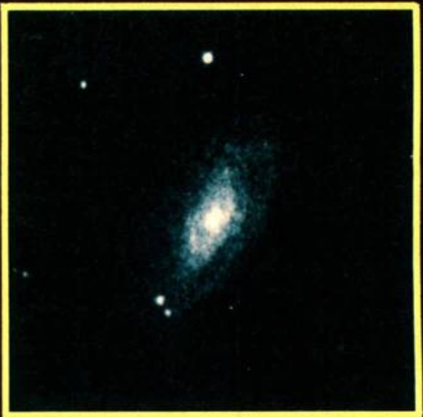

1/4"
1"
1"
1/4"
3"
BEARING RETAINER
(LOWER PIECE INVERTED)
3/4"
3/8" NUTS
MUFFLER CLAMP
4"
PROTECTIVE FABRIC STRIPS (1" WIDE)

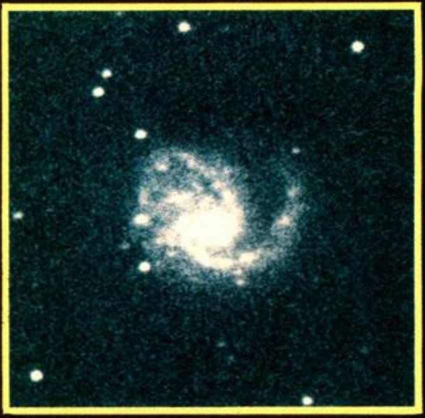




Above: M-64, the Blackeye Galaxy, is the brightest galaxy in Coma Berenices. Its dust patch is visible to 4-inch scopes on good nights. Photo by Jack Newton. Top right: Another Newton photograph shows NGC-4565, the finest example of an edge-on spiral in the entire sky. Its broad dark lane is visible in 6-inch telescopes. Middle right: Tom Dessert photographed the sharp stellar nucleus and faint outer halo of spiral M-88, one of the best sights in the Virgo cluster. Bottom right: The delicate three-arm spiral shape of M-99 is captured in this Lee Coombs photo. Ten-inch telescopes on dark nights show this spiral structure. Below: M-53, an eighth-magnitude globular, is partially resolved at high power in backyard scopes. Photo by Jack Newton.







Coma Berenices

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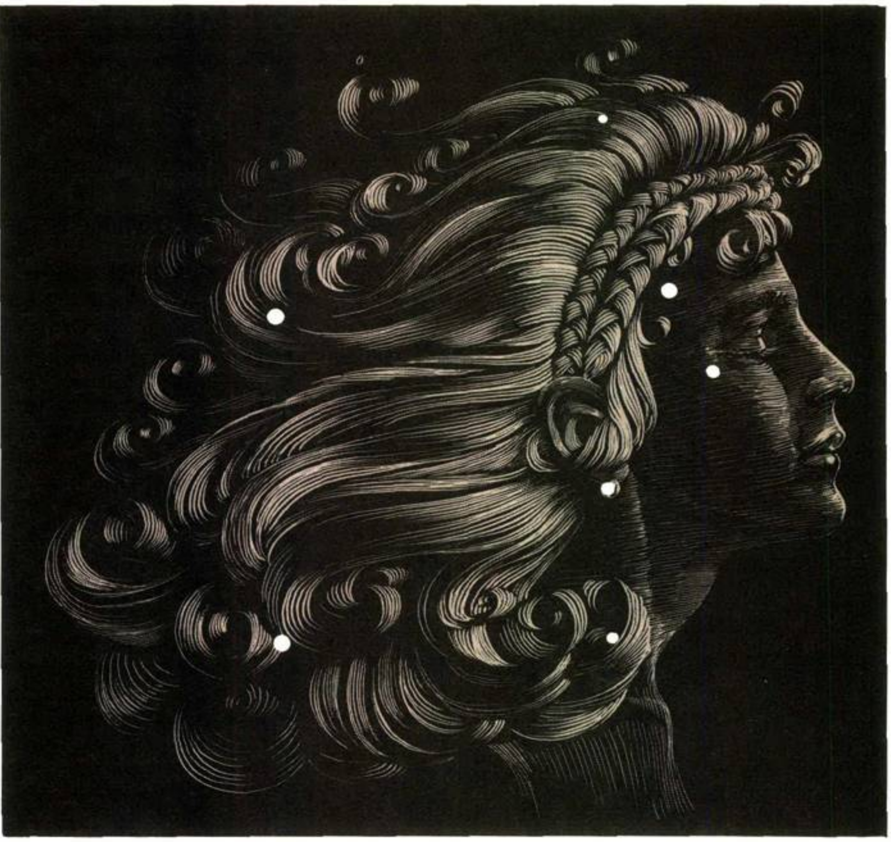
Comae Berenices


Keith Ward

In the direction of the small irregular group of stars known as Coma Berenices — Berenice's Hair — lies one of the densest concentrations of external galaxies visible to us. Looking in this direction allows us to see toward the Virgo cluster of galaxies, the heart of which lies across the border in Virgo. Several dozen bright examples of spirals, ellipticals, lenticulars, and peculiar galaxies are visible in small telescopes, many within the same low-power field of view. Coma Berenices also holds the north galactic pole, the imaginary point in the sky positioned 90° above all points on the galactic equator.

The constellation's outstanding feature is not a galaxy, but rather a large, loose open star cluster called **Mel 111** — for the astronomer P.J. Melotte, who catalogued it in 1915 — or the Coma star cluster. It is more obvious to the naked eye than the Pleiades or the Beehive cluster, as it measures a whopping 6° in diameter and glows at magnitude 2.9. The Coma cluster is one of the finest areas for scanning with binoculars, although telescopes don't show much of anything due to their limited fields of view. This group is composed of 47 stars totaling some 100 solar masses; the brightest are the fifth magnitude suns 12, 13, 14, 16, and 21 Comae Berenices. At a distance of 75 parsecs, the Coma cluster is the third nearest open star cluster after the Hyades in Taurus and the Ursa Major Moving Group.

Only 3° from the north galactic pole and 1.7° east of the star 17 Comae Berenices (close to the Coma cluster) lies **NGC-4565**, the best and brightest example of an edge-on spiral galaxy in the sky. With a 2-inch telescope, you'll see a small thin streak of light; a 4-inch at high power reveals a thicker needle of nebulosity and a hint of the central bulge about the galaxy's nucleus. NGC-4565 measures 15.5′ x 2.1′ in diameter and has a magnitude of 10.7; on good nights an 8-inch at high power shows a long nebulosity with a broad dust band running alongside its edge, and a bright starlike nucleus embedded in the roundish central bulge. This Sb-type galaxy is probably 10 megaparsecs distant, and is possibly an outlying member of the Virgo cluster, although it lies some 13° north of the cluster's heart.

For information on naked-eye sky viewing, including planets, constellations, and mythology, see **Eye on the Sky**.

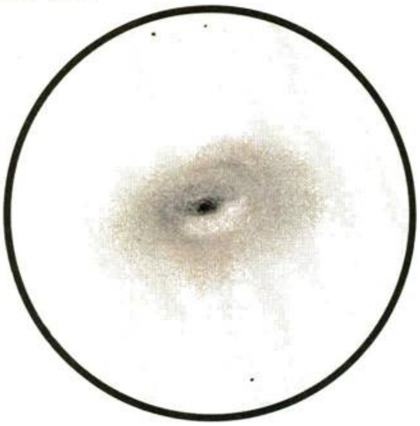
Just 2° north of NGC-4565 is the bright Sc-type spiral **NGC-4559**, a galaxy measuring 10.0′ x 3.0′ and glowing at magnitude 10.5. This galaxy is composed of several coarse knotty arms; on dark nights large backyard telescopes may show a mottled condensation within the galaxy's halo, corresponding to dust lanes and bright gas clouds in the galaxy's arms. A 4-inch shows a bright oval smudge with a condensed nucleus.

On the other side of the north galactic pole from the NGC-4565 area, about 2.3° west of Beta [β] Comae Berenices, lies the tiny dim elliptical galaxy **NGC-4889**. This little speck of light shines at magnitude 13.2, measures 1.0′ x 0.6′, and is classed as an E4 galaxy. Through small telescopes NGC-4889 looks like a small, dim planetary nebula; its great distance of 130 megaparsecs masks its great size and causes it to appear unimpressive. This is the principal member of the Coma Berenices cluster of galaxies, a group much like the Virgo cluster but 20 times farther away. At least 1000 galaxies are members of this group, scattered across about 3° and centered on NGC-4889, but these systems are very faint, most being 15th magnitude and fainter.

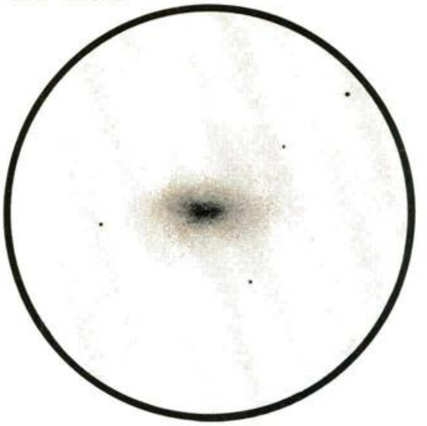
In the eastern part of the constellation, 1° northwest of the binary Alpha [α] Comae Berenices, lies the globular cluster **M-53** (NGC-5024). This cluster has a total magnitude of 8.7 and a diameter of 14.0′, making it a nice example of a globular under low-power viewing — a 6-inch at 50x shows a crisply defined ball of stars, grainy at the edges and milky white in its center. Only 1° southeast is the peculiar globular cluster **NGC-5053**, a sparse system containing only 3,400 stars, compared to the Hercules cluster's one million stars. This loose group measures 8.9′ across and glows at magnitude 10.9, making it visible in a 6-inch as a grainy patch of weak light.

Midway between α Comae and the Coma cluster lies the bright star 35 Comae Berenices. One degree (one low-power telescopic field) east-northeast of this star is the beautiful eighth-magnitude system **M-64** (NGC-4826), the "Blackeye Galaxy." One of the brightest and most easily observed galaxies anywhere in the sky, it received its nickname for a dust patch superimposed across its face. This black eye is visible in even a 4-inch telescope at a good site, and is comfortably visible in a 6-inch from most observing sites. A good 8-inch scope shows the dark patch, a sharp condensed

M-64

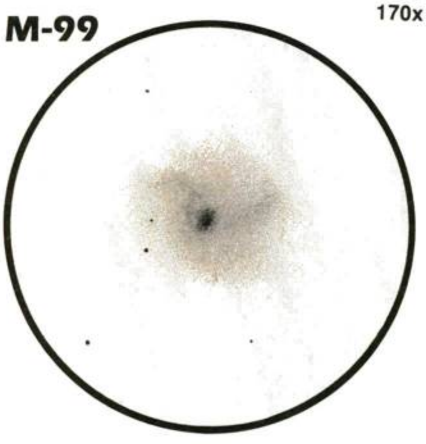


M-100



8-inch SCT
170x

M-99



Sketches by David J. Eicher

nucleus, bright ringlike core, and a large outer envelope of faint gas. This Sb galaxy (some astronomers say Sa) lies roughly 9 megaparsecs away and shines with the luminosity of 13 billion Suns. Curiously, not one supernova has ever been recorded in this galaxy.

In the western part of the constellation, near the Leo border, lies the bright star **2 Comae Berenices**. This is a fine, relatively fixed binary system composed of magnitude 6.0 and 7.5 stars separated by 3.6″ in position angle 237°. As the distance between the spectral type A8 and F2 components is pretty close, find this star and then "crank up" to the highest usable power that delivers a smooth, steady image. You should be able to split the stars handily when the seeing is good. Another double in the constellation is **24 Comae Berenices**, an exquisite wide pair composed of magnitude 5.0 and 6.5 stars separated by 20.3″ in p.a. 271°. The K2- and A7-type stars show as yellow and bluish suns, the K2 star being the brighter. Perhaps Coma's finest variable star is the long-period variable **R Comae Berenices**, which changes in brightness from magnitude 7.5 to fainter than 14 in a period of 362 days. Since its period is almost exactly a year, estimating the brightness of this star once a week will give you a good prospect for an annual observing program.

Now we move south, approaching the border with Virgo; this is the direction of the main body of the Virgo cluster, the largest concentration of galaxies in our part of the universe. About 5° north of the cluster's heart, we find **M-85** (NGC-4382), a bright lenticular system measuring 3.0′ x 2.0′ across and shining at magnitude 10.5. In small telescopes it appears as a ball of fuzz showing little structure save for a condensed nuclear region. The distance to this system is about 13 megaparsecs, and it holds about 100 billion solar masses. The barred spiral galaxy NGC-4394 lies 7.8′ east of M-85.

The loose Sc-type spiral **M-100** (NGC-4321), the largest spiral in the Virgo cluster, is a much better eyepiece target. Its dimensions of 5.2′ x 5.0′ and magnitude of 10.4 — suggesting a roughly face-on inclination — provide a view of the nucleus and a faint hazy envelope of matter encapsulating it. With large amateur scopes some dust structure is visible, but only on supremely good nights. In 1979 a bright (12th magnitude) supernova erupted in this system, offering backyard telescopists a good view for over two weeks.

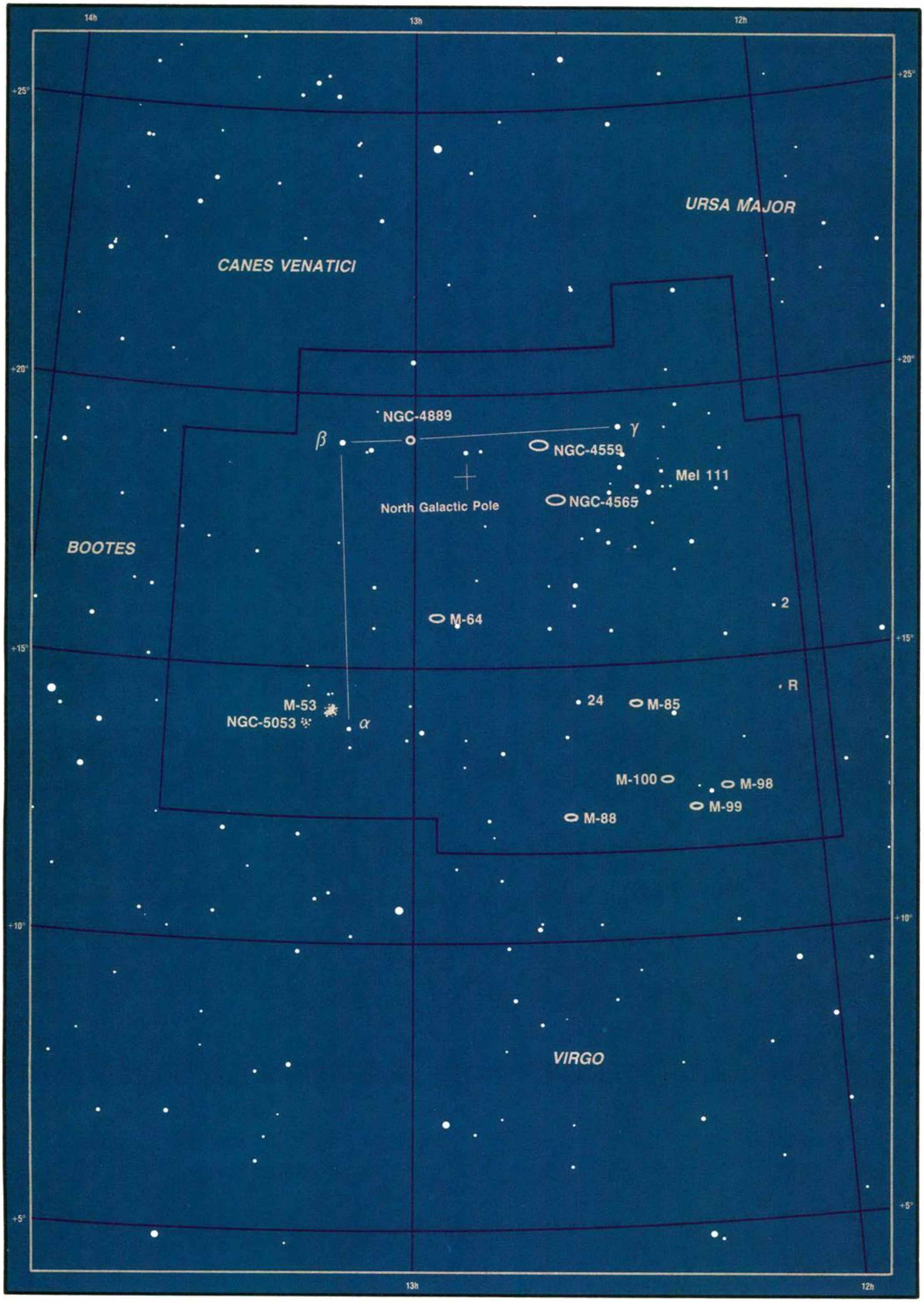
M-98 (NGC-4192) is an elongated nearly edge-on type Sb spiral, measuring 8.2′ x 2.0′ and shining at magnitude 11.0. This galaxy's surface brightness is rather low, making it a tricky object at high power. Backyard telescopes show this galaxy as a thin streak of greenish light, slightly curved, showing a faint envelope of gas and a sharp nucleus. Its neighbor **M-99** (NGC-4254), on the other hand, is a face-on type Sc spiral showing a bright hub, sharp nucleus, and faint outer haze suggesting spiral arms in a 6-inch on dark nights. A 10-inch at high power easily shows spiral structure in M-99 under dark skies. This system is a magnitude 10.4, 4.5′ x 4.0′ roundish glow.

The multiple arm galaxy **M-88** (NGC-4501), a magnitude 10.5 system measuring 5.7′ x 2.5′, is a fine sight in backyard instruments. It is inclined 30° from edge-on with respect to our line of sight, giving it a nice high surface brightness and a willingness to withstand high magnification. One of the better objects in the Virgo cluster for small scopes, it shows a broad elongated central glow and a large outer envelope of nebulosity.

Object	**M#**	**Type**	**R.A. (2000)**	**Dec.**	**Mag.**	**Size/Sep./Per.**	**H**
R CrB		LPV	12h 04m	+18°47′	7.5-14.0	362d	
2 CrB		★^{2}	12h 04m	+21°27′	6.0,7.5	3.6″	
NGC-4192	M-98	∮	12h 15m	+14°54′	11.0	8.2′x2.0′	Sb
NGC-4254	M-99	∮	12h 19m	+14°25′	10.4	4.5′x4.0′	Sc
NGC-4321	M-100	∮	12h 23m	+15°49′	10.4	5.2′x5.0′	Sc
Melotte 111		⊙	12h 25m	+25°43′	2.9	360′	
NGC-4382	M-85	0L	12h 25m	+18°11′	10.5	3.0′x2.0′	S0
NGC-4501	M-88	∮	12h 32m	+14°26′	10.5	5.7′x2.5′	Sb
24 CrB		★^{2}	12h 35m	+18°23′	5.0,6.5	20.3″	
NGC-4559		∮	12h 35m	+27°57′	10.5	10.0′x3.0′	Sc
NGC-4565		∮	12h 36m	+26°00′	10.5	15.0′x1.1′	Sb
NGC-4826	M-64	∮	12h 57m	+21°41′	8.6	7.5′x3.5′	Sa/Sb
NGC-4889		0	13h 00m	+27°59′	13.2	1.0′x0.6′	E4
NGC-5024	M-53	●	13h 13m	+18°10′	8.0	10.0′	
NGC-5053		●	13h 16m	+17°41′	10.5	8.0′	

H = Hubble classification type for galaxies

★^{2}	*Double Star*
LPV	*Long Period Variable*
⊙	*Open Cluster*
●	*Globular Cluster*
∮	*Spiral Galaxy*
0	*Elliptical Galaxy*
0L	*Lenticular Galaxy*


14h
13h
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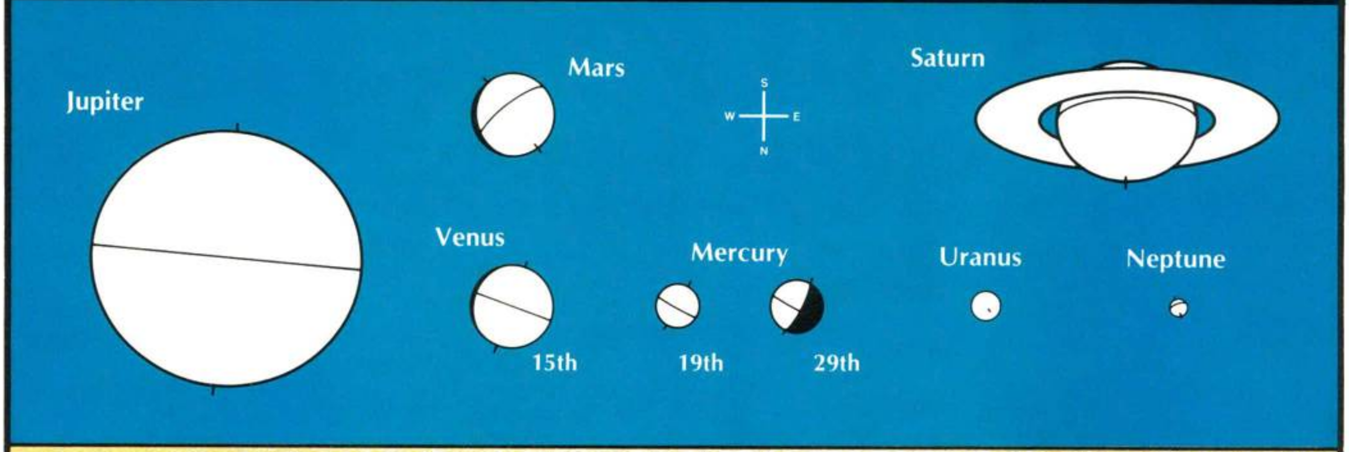
+25°
+20°
+15°
+10°
+5°
URSA MAJOR
CANES VENATICI
NGC-4889
β
γ
NGC-4559
Mel 111
North Galactic Pole
NGC-4565
BOOTES
M-64
2
R
24
M-85
M-53
NGC-5053
α
M-100
M-98
M-99
M-88
VIRGO
13h
12h

Planetary Data

March 1984


Jupiter
Mars
S
W
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N
Saturn
Venus
15th
Mercury
19th
29th
Uranus
Neptune

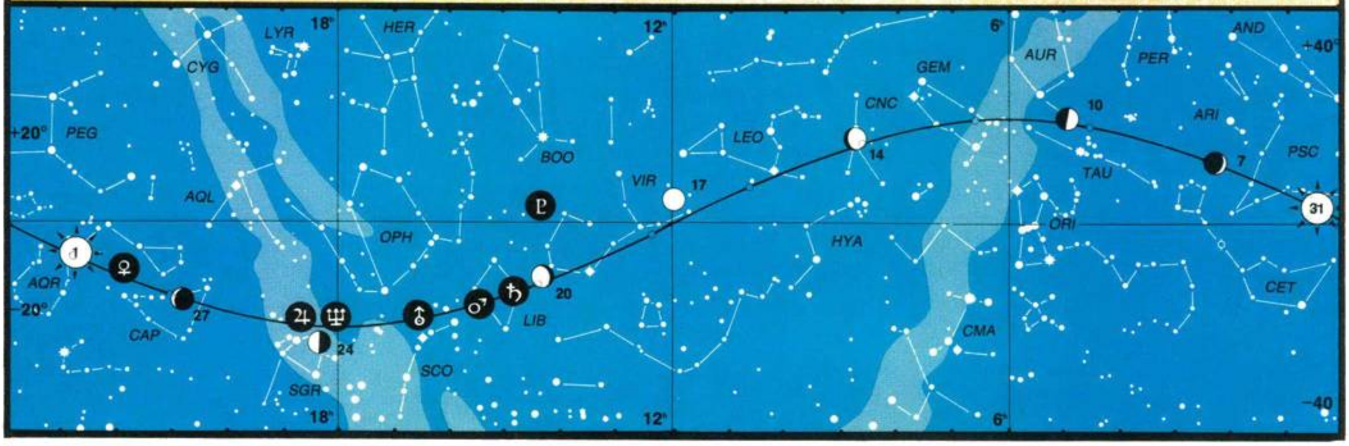
		Date	Mag.	Angular Size	% Illum.	Distance (AU) from: Earth	Sun	Longitude: Heliocentric	Ecliptic	R.A. (2000.0)	Dec.
Sun		1	−26.8	32.3′	—	0.99	—	—	340°36.3′	22h 49.2m	− 7°30.7′
		15	−26.8	32.2′	—	0.99	—	—	354°36.4′	23h 41.0m	− 2°03.6′
		31	−26.7	32.1′	—	1.00	—	—	10°28.4′	0h 39.3m	+ 4°13.8′
Mercury	☿	1	−1.1	4.9″	98%	1.38	0.41	317°48.9′	333°31.2′	22h 27.4m	−11°55.1′
		15	−1.6	5.2″	98%	1.31	0.33	18°52.7′	0°10.6′	0h 04.5m	− 0°28.4′
		31	−0.4	7.0″	53%	0.97	0.32	115°32.1′	28°28.8′	1h 45.4m	+13°10.2′
Venus	♀	1	−3.9	11.5″	89%	1.45	0.73	274°40.3′	312°50.9′	21h 04.6m	−17°16.3′
		15	−3.9	11.0″	92%	1.51	0.73	296°48.8′	330°07.2′	22h 13.0m	−12°10.6′
		31	−3.9	10.6″	94%	1.58	0.73	322°07.1′	349°51.9′	23h 27.5m	− 5°03.3′
Mars	♂	15	−0.2	10.7″	92%	0.88	1.61	203°04.1′	235°11.8′	15h 36.2m	−17°47.2′
Jupiter	♃	15	−2.1	36.2″	99%	5.43	5.26	269°21.2′	279°21.5′	18h 43.9m	−22°49.2′
Saturn	♄	15	+0.4	18.0″	100%	9.20	9.85	221°32.0′	225°34.3′	14h 58.3m	−14°17.1′
Uranus	⛢	15	+5.6	3.7″	100%	18.78	19.00	250°37.9′	252°55.5′	16h 49.7m	−22°24.7′
Neptune	♆	15	+8.0	2.2″	100%	30.36	30.26	269°28.1′	270°45.9′	18h 06.8m	−22°14.9′
Pluto	♇	15	+13.7	0.1″	100%	29.07	29.84	210°29.9′	211°08.1′	14h 22.7m	+ 4°09.6′

Universal Time

Astronomers the world over use an unambiguous system of time reckoning — Universal Time (UT) — based on a 24 hour clock. Times in The Backyard Astronomer are UT unless otherwise noted. To convert UT into your local standard time, subtract the following number of hours for each time zone: EST, 5; CST, 6; MST, 7; PST, 8; Alaska 9; and Hawaii, 10. For example, if an event is to happen at 03:00 hours UT on February 2, then EST for the event is 10 p.m., February 1. Likewise, 03:00 UT on March 5 becomes, in PST, 7 p.m, March 4.

Moon Data

New Moon. . . . . March 2 at 18:31
First Quarter. . . . . March 10 at 18:27
Full Moon. . . . . March 17 at 10:10
Last Quarter. . . . . March 24 at 7:58
New Moon. . . . . April 1 at 12:10
Perigee: March 2 at 10:54. . . . 406,712 km.
Apogee: March 16 at 21:12. . . . 357,150 km.
Perigee: March 29 at 16:07. . . . 406,345 km.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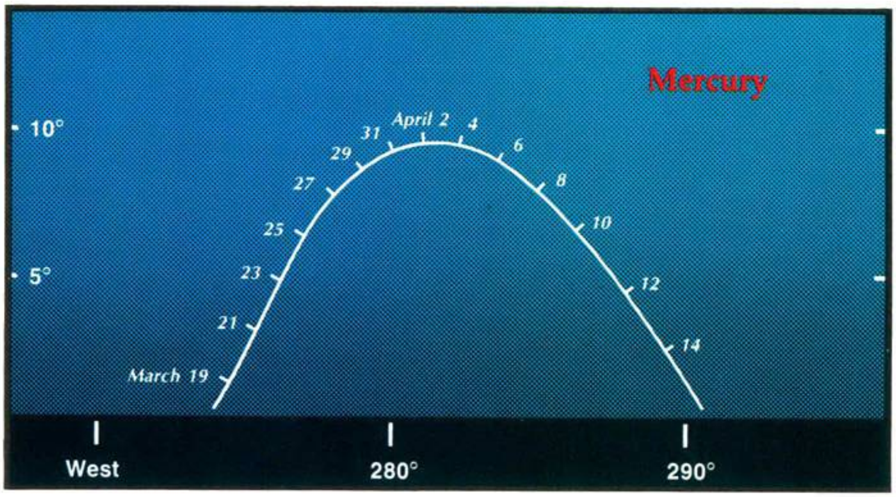

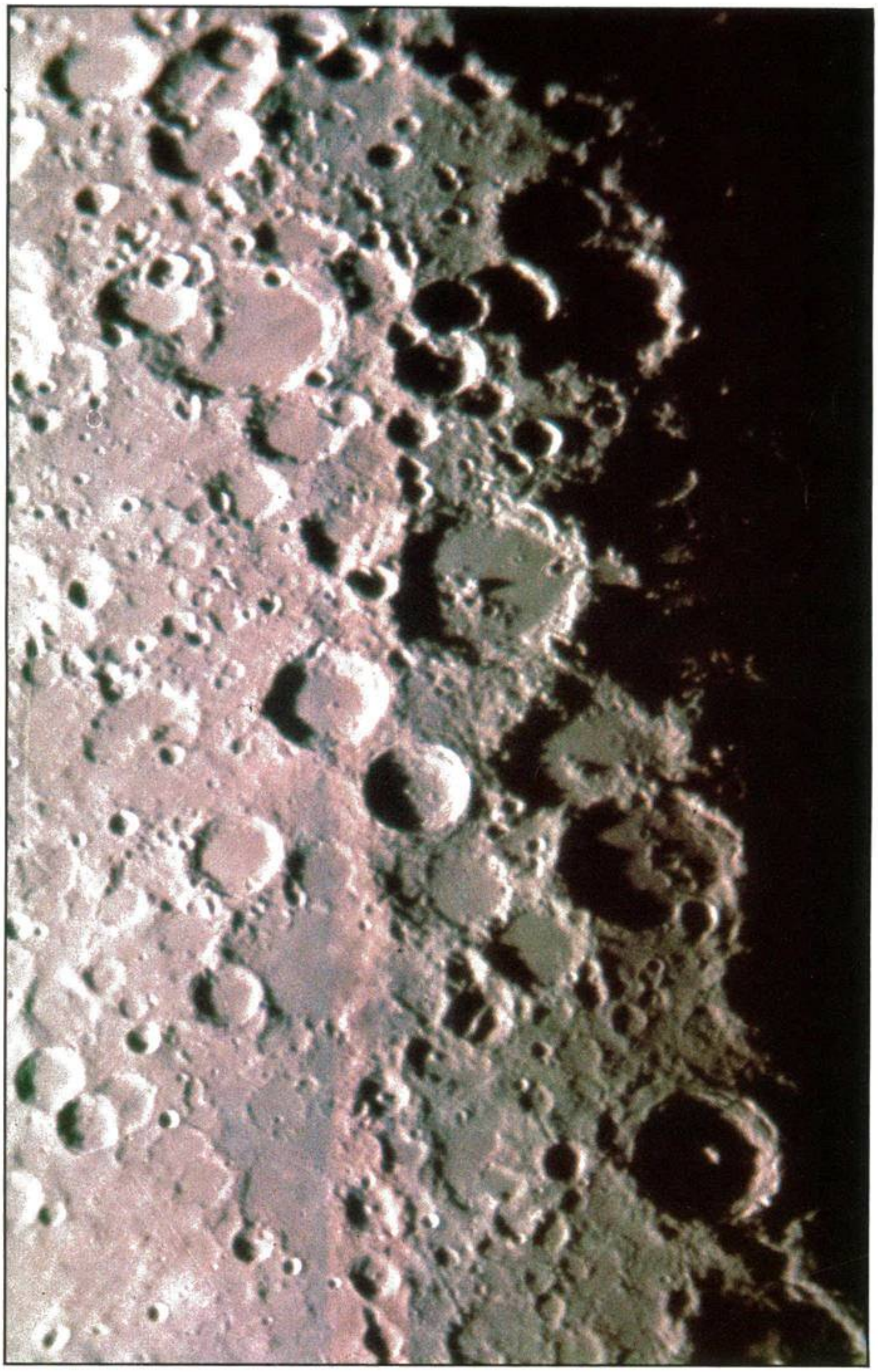

Right top: Mercury in the evening sky, 45 minutes after sunset. Below: Lunar highlands near Mare Nubium. Photo by Jean Dragesco (400 speed film, 14-inch SCT, 1-second exposure at f/60).

Mercury

Some time around the third week of March, Mercury will pop into view over the western horizon after sunset. This is the beginning of the year's best apparition for the innermost planet. (See diagram at right.) Between late March and the middle of April, when it ducks below the horizon again, Mercury will rise to almost 10° high (45 minutes after sunset). Greatest elongation occurs on April 3rd.

During this time, a telescope will show the planet's phases change from 92% lit on March 19th to 13% lit on April 12th. Its apparent size will almost double from 5.4'' of arc across to 9.8''. But keep your eyepiece powers relatively low — otherwise you'll simply be magnifying the defects caused by poor atmospheric seeing near the horizon.

Venus

Though it remains a bright object in the morning sky, Venus is a disappointment telescopically. Besides its fairly low predawn elevation (which causes seeing problems), the planet just hasn't anything to show on its disk. Many Venus observers prefer to observe the planet during twilight. Since Venus rises before the Sun, it is easy to locate the planet and then just keep watching it as dawn comes on.

Eventually the sky will brighten too much, but for a while you'll find that the brilliantly lit disk (about 92% "Full") is comfortably balanced by the brightening sky — reducing an otherwise painfully glaring contrast.

Earth

The vernal (spring) equinox occurs at 10:24 UT on March 20th, as the center of the Sun crosses the celestial equator northward.

Mars

Mars rises about three to six hours after the Sun sets (depending on whether it is late or early March) and by sunrise is well down in the west. Opposition and best viewing come on May 11, but don't wait until then to observe it — get in practice now.

As the apparent size of Venus dwindles, that of Mars is growing steadily; in mid-March they are equally large. Unlike Venus' blankly white disk, Mars displays a lot of features. Watch for clouds that can come and go, especially near the sunset terminator — or follow the slow progression of dark markings as Mars' rotation carries them across the disk.

Asteroids

1 Ceres is in conjunction with the Sun on March 22nd; it cannot be seen this month.

2 Pallas (magnitude 10.5) is moving northeastward from northern Aquarius into southwestern Pegasus. Its positions:

9th: 21h 37m 16s, +2° 50.5'

This 1983 Perseid shot won Mike Shin this month's "Best Astro-Photo" award. He used a 50 mm lens at f/1.8 and a 10-minute exposure on 400 speed film.

19th: 21h 49m 22s, +3° 36.0′

Pallas rises around 5 a.m. local time in mid-March.

3 Juno (9.6) lies in Taurus to the southwest of the Hyades star cluster. Its positions:

9th: 3h 49m 31s, +7° 39.4′

19th: 4h 08m 51s, +9° 15.0′

Juno sets about 11 p.m. local time on March 15th.

4 Vesta (8.1) is moving eastward in Taurus and heading toward M-1, the Crab Nebula. It will pass 1° 33′ north of that object at 4:50 UT on April 1. Its positions:

9th: 5h 07m 31s, +22° 27.0′

19th: 5h 18m 03s, +22° 58.1′

Vesta sets around 1 a.m. local time in the middle of the month.

For convenience in plotting their positions in a star atlas, all asteroid coordinates are for the epoch 2000.0.

Jupiter

In terms of where it lies on the ecliptic — the path of the planets — Jupiter is at the "bottom," near its lowest average declination. Thus, although it is crossing the meridian in the south as the Sun comes up, it is still only some 27° high.

In your scope, Jupiter's disk will have an equatorial diameter of about 36″ (the pole-to-pole measurement is about 2.5″ less). See if you can "spot the Spot" — the Great Red Spot, which considering how it often appears, might be described better as the Great Pinkish-Grey Spot. It lies in the mid-southern jovian latitudes, and crosses the center of the disk every 9h 55m.

Saturn

Saturn is at opposition on May 3rd, and can be seen rising about 11 p.m. local time on March 15th. It lies on the western side of Libra's four-star triangle, near Alpha (α) Librae itself.

In your scope, Saturn presents a splendid view — the north side of the rings are tipped 21° toward you, and they spread some 41″ of arc. To gain an appreciation for the size of the ring system, bear in mind that they measure some 21 Earths across!

Uranus

The easiest way to locate Uranus is to use the finder chart on page 83 of the January issue. Look for a magnitude 5.6 dot of light 3.7″ of arc in diameter. If you're using binoculars, you'll find it more easily in a month or two — right now, Uranus has very little motion among the stars.

Neptune

As with Uranus, your best approach with Neptune is to use the finder map in the January issue. Neptune appears as a grey disk, 2.2″ of arc in size and at magnitude 8.0. It has a very slow eastward motion.

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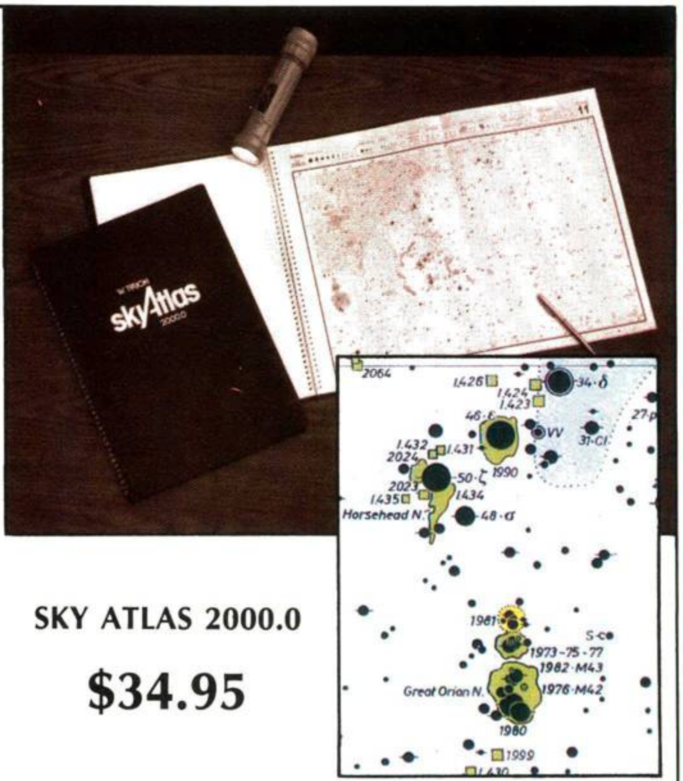
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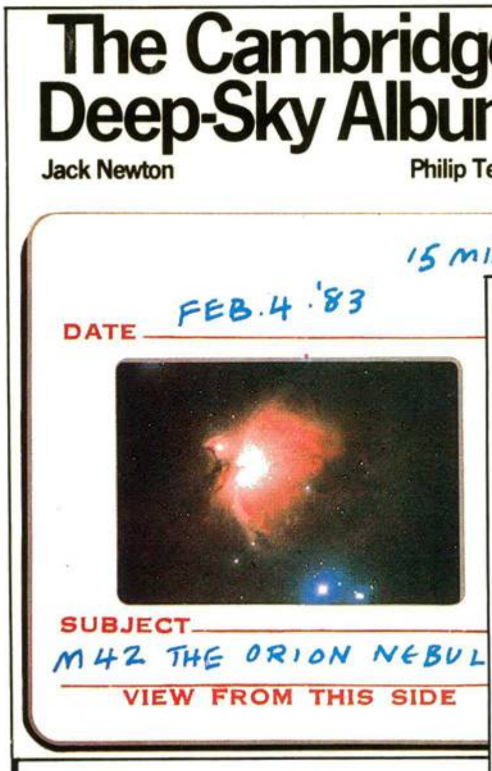
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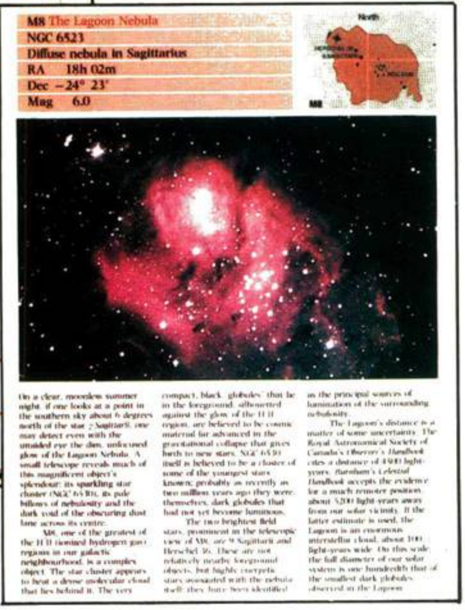

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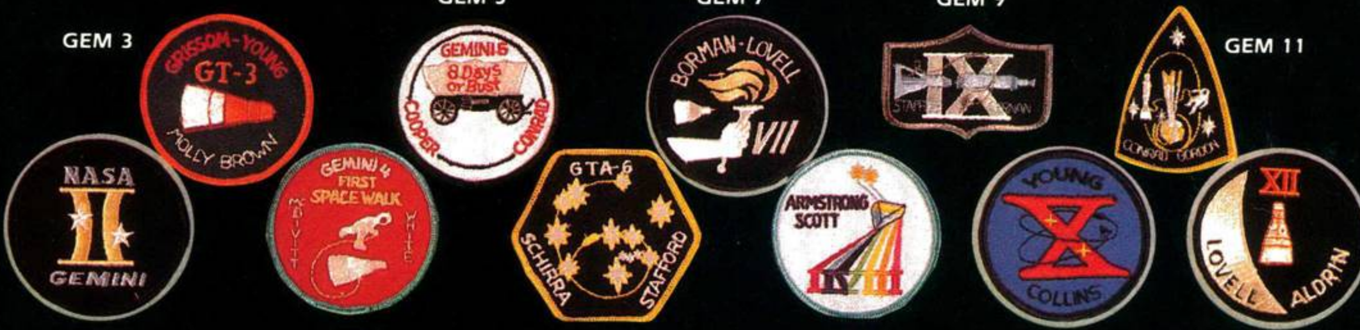
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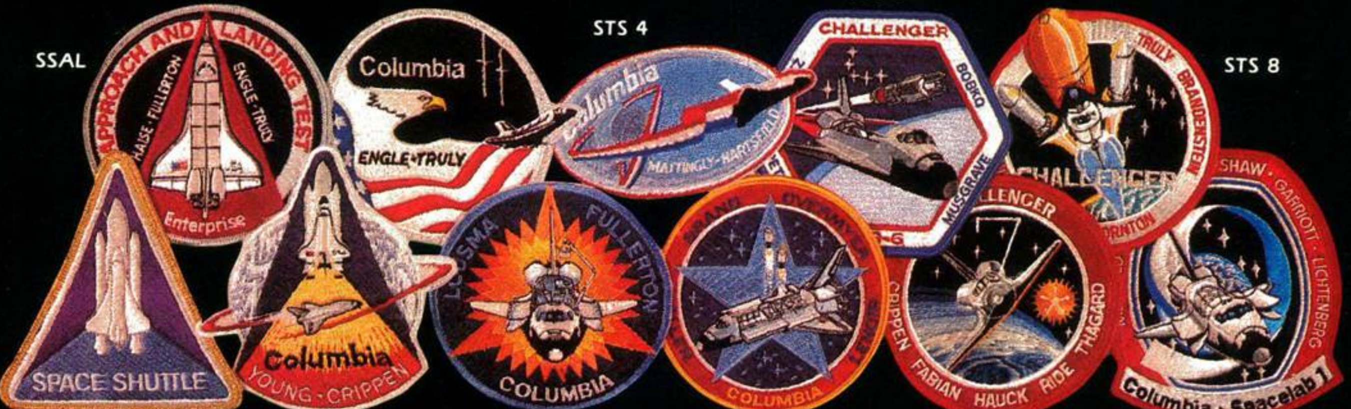
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